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Geohydrology and Water Chemistry of the Alexander Valley, Sonoma County, California

Scientific Investigations Report 2006-5115

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Cover. Photograph of Alexander Valley,
Sonoma County, California,
by GAMA program staff, U.S. Geological Survey

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By Loren F. Metzger, Christopher D. Farrar, Kathryn M. Koczot, and
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U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors, Datum, Abbreviations, and Acronyms

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), unless otherwise noted. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (μg/L).

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

Abbreviations and Acronyms

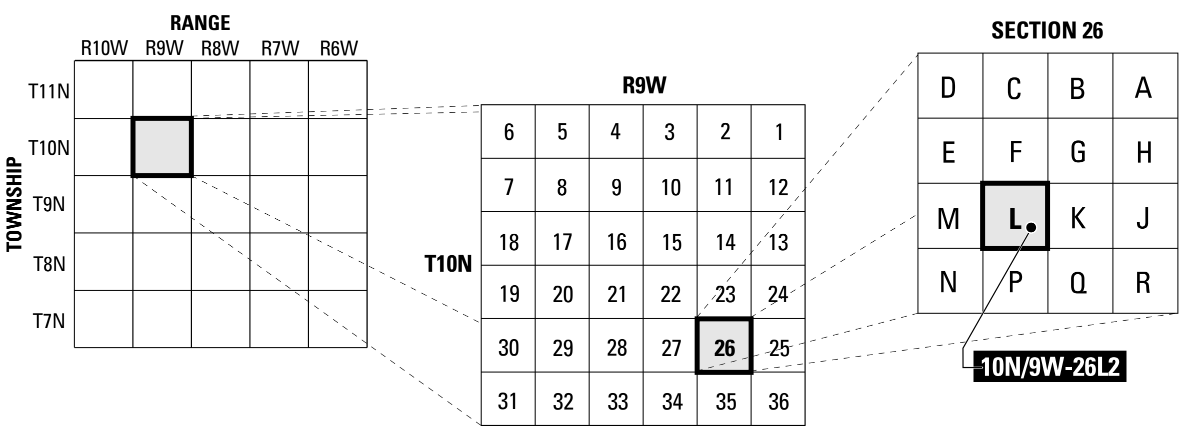
bls	below land surface
EC	electrical conductance
ET	evapotranspiration
ET_a	actual evopotranspiration
ET_o	potential evapotranspiration
GAMA	Ground-Water Ambient Monitoring and Assessment program
GIS	geographical information system
ma	millions of years before present
meq/L	milliequivalent per liter
mg/L	milligrams per liter
NGVD 29	National Geodetic Vertical Datum of 1929
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
R^2	correlation coefficient
ROE	residue on evaporation
SMD	soil moisture deficit
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
WY	water year

Organizations

CADWR	California Department of Water Resources
SCWA	Sonoma County Water Agency
SWRCB	California State Water Resources Control Board
USGS	U.S. Geological Survey

Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with “A” in the northeast corner of the section and progressing in a sinusoidal manner to “R” in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). All wells in the study area are referenced to the Humboldt base line and meridian (H). Well numbers consist of 15 characters and follow the format 010N009W-026L002. In this report, well numbers are abbreviated and written 10N/9W-26L2. Wells in the same township and range are referred to only by their section designation, -26L2. The following diagram shows how the number for well 10N/9W-26L2 is derived.



Well-numbering diagram

Geohydrology and Water Chemistry of the Alexander Valley, Sonoma County, California

By Loren F. Metzger, Christopher D. Farrar, Kathryn M. Koczot, and Eric G. Reichard

Abstract

This study of the geohydrology and water chemistry of the Alexander Valley, California, was done to provide an improved scientific basis for addressing emerging water-management issues, including potential increases in water demand and changes in flows in the Russian River. The study tasks included (1) evaluation of existing geohydrological, geophysical, and geochemical data; (2) collection and analysis of new geohydrologic data, including subsurface lithologic data, ground-water levels, and streamflow records; and (3) collection and analysis of new water-chemistry data.

The estimated total water use for the Alexander Valley for 1999 was approximately 15,800 acre-feet. About 13,500 acre-feet of this amount was for agricultural use, primarily vineyards, and about 2,300 acre-feet was for municipal/industrial use. Ground water is the main source of water supply for this area.

The main sources of ground water in the Alexander Valley are the Quaternary alluvial deposits, the Glen Ellen Formation, and the Sonoma Volcanics. The alluvial units, where sufficiently thick and saturated, comprise the best aquifer in the study area.

Average recharge to the Alexander Valley is estimated from a simple, basinwide water budget. On the basis of an estimated annual average of 298,000 acre-feet of precipitation, 160,000 acre-feet of runoff, and 113,000 to 133,000 acre-feet of evapotranspiration, about 5,000 to 25,000 acre-feet per year is available for ground-water recharge. Because this estimate is based on differences between large numbers, there is significant uncertainty in this recharge estimate.

Long-term changes in ground-water levels are evident in parts of the study area, but because of the sparse network and lack of data on well construction and lithology, it is uncertain if any significant changes have occurred in the northern part of the study area since 1980. In the southern half of the study area, ground-water levels generally were lower at the end of the 2002 irrigation season than at the end of the 1980 season, which suggests that a greater amount of ground water is being pumped in the southern half of the study area in recent years compared with that pumped in the early 1980s.

Water-chemistry data for samples collected from 11 wells during 2002–04 indicate that water quality in the study area generally is acceptable for potable use. Two wells, however, each contained one constituent (241 µg/L of manganese and 1,350 µg/L of boron) in excess of the recommended standards for drinking water (50 µg/L and 1,000 µg/L, respectively).

The chemical composition of water from most of the wells sampled for major ions plot as a mixed cation-bicarbonate, magnesium-bicarbonate, or calcium-bicarbonate type water. The ionic composition of the historical and recent samples from wells in the Alexander Valley is similar to that of the historical surface-water samples collected from the Russian River near Healdsburg. This suggests a similar source of water, particularly for wells that are less than 200 feet total depth and perforated in Quaternary alluvial deposits. Water from deeper, non-alluvial wells may contain slightly higher concentrations of sodium as a result of cation exchange.

Water samples collected from several wells over an approximately 30–year period suggest a progressive change in water chemistry over time. Samples from the southern part of the valley show a trend towards higher ionic concentrations and increasing concentrations of particular constituents such as sulfate.

Introduction

The Alexander Valley is a topographically defined ground-water basin in northern Sonoma County, California. Sonoma County is in the northern part of the greater San Francisco Bay region, an area of northern California that has experienced rapid population growth and accelerated urbanization during the past 30 to 40 years. The Alexander Valley has undergone significant changes in land use, mostly involving the conversion from native vegetation to irrigated vineyards. The ground-water system in the Alexander Valley is closely linked to the Russian River. Increased pumpage has affected some ground-water levels in the valley; future changes in pumpage will likely affect recharge and discharge rates from the river. Conversely, possible future changes in the flow regime of the Russian River could affect the ground-water levels in the Alexander Valley. Changes in land use and in the ground-water flow system in the Alexander Valley may affect the sources and transport of potential contaminants to ground water and the Russian River.

The U.S. Geological Survey (USGS) began a study to improve the understanding of the geohydrology and geochemisty of the Alexander Valley in order to gain knowledge regarding potential future changes in the ground-water/surface water system. The project is part of a multi-phase USGS study of the ground-water resources of Sonoma County being conducted in cooperation with the Sonoma County Water Agency (SCWA). In addition, wells in the area have been sampled as part of the statewide California Ground-Water Ambient Monitoring and Assessment (GAMA) program, which is being done by the USGS in conjunction with the California State Water Resources Control Board (SWRCB).

Purpose and Scope

The USGS, in cooperation with SCWA, undertook this study to evaluate the ground-water resources of Alexander Valley. The goals of the study were to update the geohydrologic characterization of the study area and to provide a current assessment of hydrologic conditions, including an evaluation of ground-water level and water-quality changes during the past 25 to 50 years.

To meet the objectives of this study, three principal tasks were undertaken: (1) evaluation of existing geohydrological, geophysical, and geochemical data; (2) collection and analysis of new geohydrologic data, including subsurface lithologic data, ground-water levels, and streamflow records; and (3) collection and analysis of new water-chemistry data (note that water-chemistry data were collected as part of the GAMA program, funded by the SWRCB).

The purpose of this report is to present a geologic and hydrologic description of the study area, present selected hydrologic data collected from the 1950s to 2004, quantify changes in the ground-water system that have occurred in the past 50 years, and quantify changes in water use. This information is essential for future management of the ground-water system, which is the primary water supply for this area of Sonoma County.

Location of the Study Area

The Alexander Valley study area is located approximately 50 miles (mi) north of San Francisco in northern Sonoma County, California. A small part of the Valley extends into southern Mendocino County (*figs. 1*, *2*). The study area comprises 127 square miles (mi^2) that includes the valley floor and the hills immediately adjacent where most of the agricultural development is located. Alexander Valley is drained by the Russian River, which discharges to the Pacific Ocean to the west of the study area. This part of the Russian River drainage basin commonly is referred to as the Middle Russian River (California Department of Water Resources, 1980). In this report, Alexander Valley refers to Alexander Valley proper and its northwestward extension, Cloverdale Valley. This designation conforms to the most recent ground-water basin delineation given by California Department of Water Resources (2004). In some reports a distinction is made between the two valleys; however, these valleys are hydraulically connected through thin deposits of alluvial materials beneath the Russian River. A series of low hills, part of the Mendocino Range, form the western boundary of the watershed, and the Mayacmas Mountains form the eastern boundary (*fig. 2*).

Land and Water Use

Land use in study area is predominantly native vegetation and agriculture (*fig. 3*, *table 1*) (California Department of Water Resources, 1974, 1999). From the 1950s to the present, the primary crop has been vineyards, followed by orchards (*table 2*) (California Department of Water Resources, 1974, 1999). Lands designated as urban, residential, commercial, and industrial purposes make up less than 5 percent of the study area. The major urban/residential areas include the communities of Preston, Cloverdale, Asti, and Geyserville, several unincorporated communities, and areas of rural and semi-rural residential development. According to the population census of 2000, about 12,000 people lived in the part of the study area located in Sonoma County (Association of Bay Area Governments, accessed November 11, 2004). Sonoma County makes up a total of 96 percent of the study area, with the remaining 4 percent located in Mendocino County.

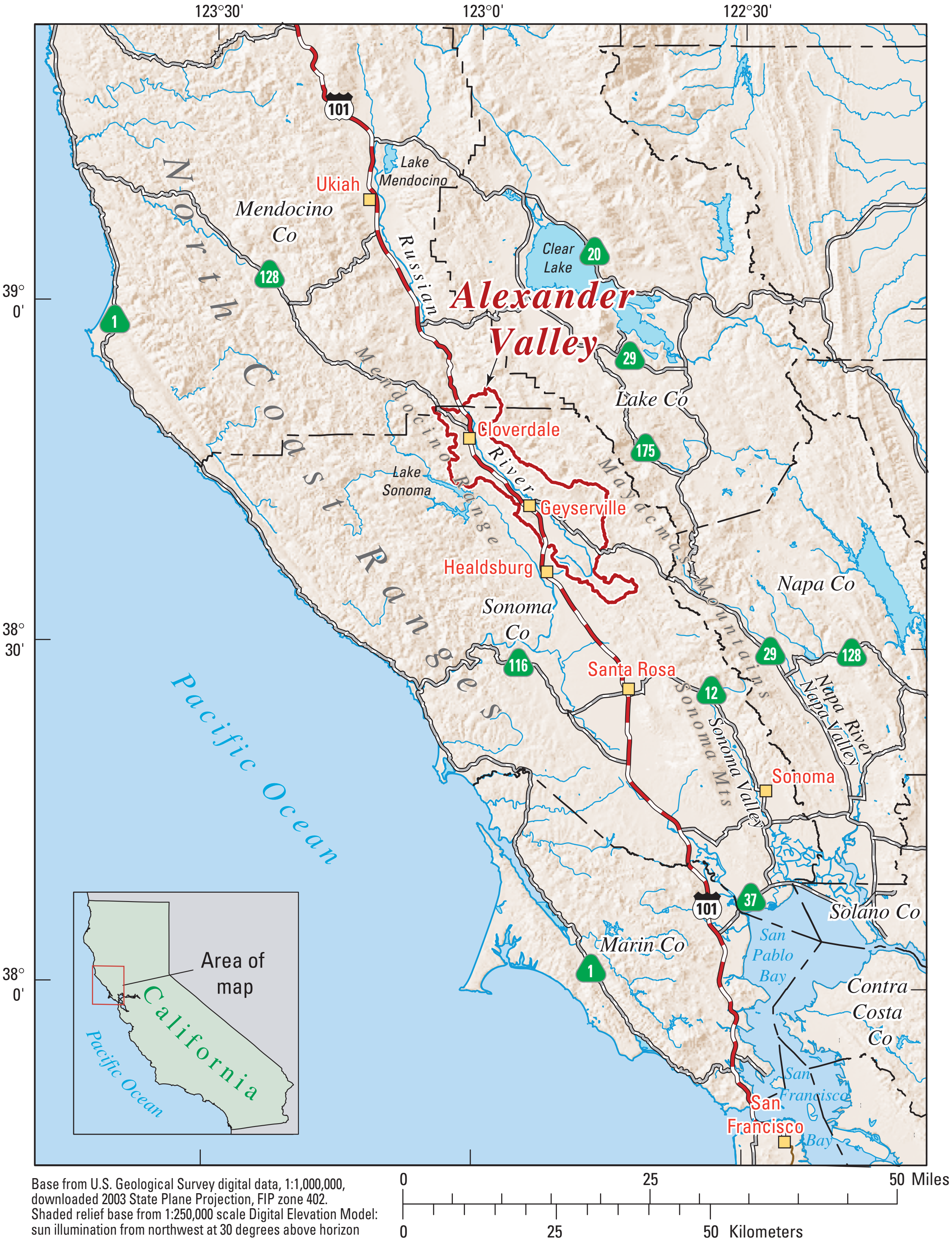


Figure 1. Location of study area.

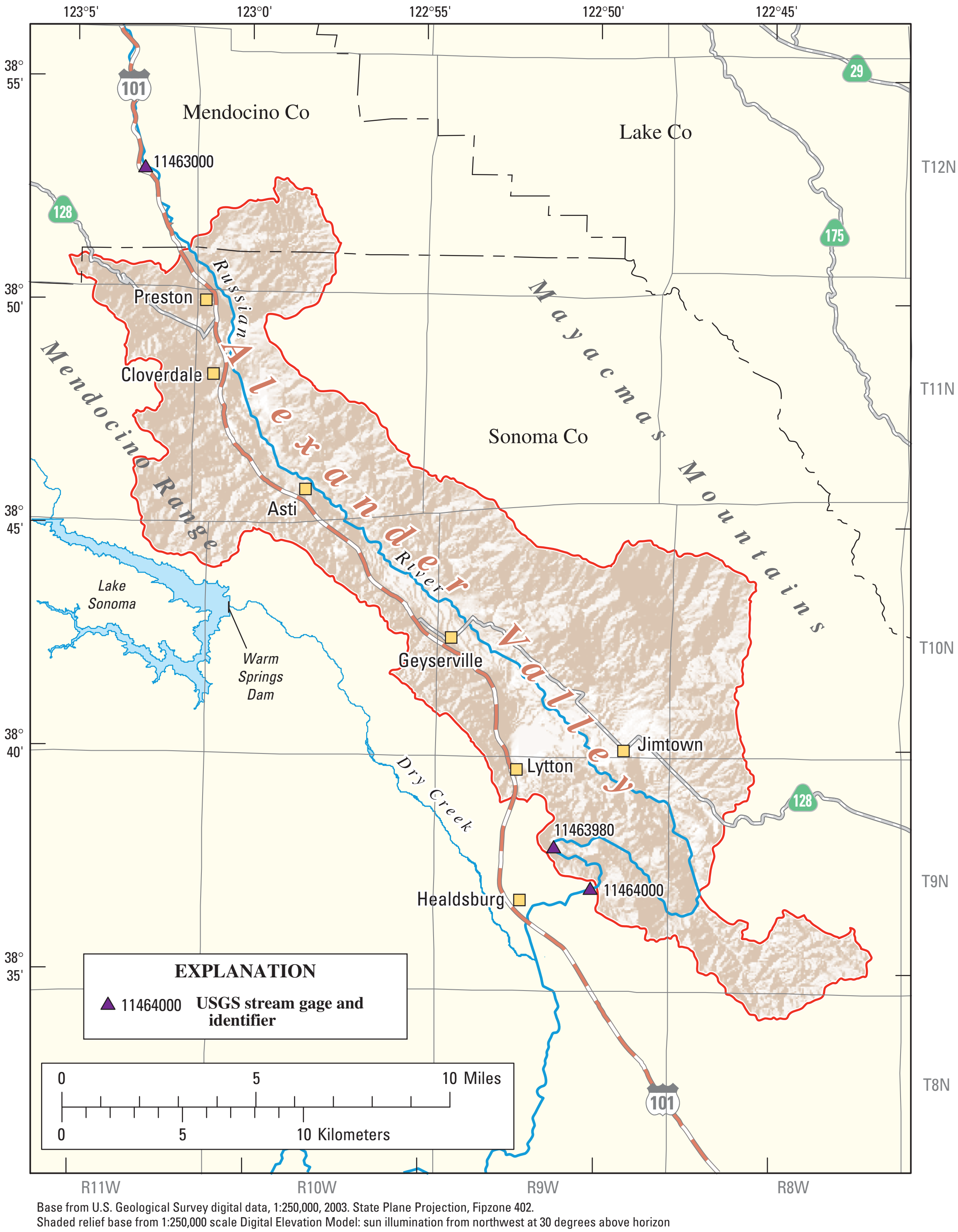


Figure 2. Location of Alexander Valley watershed, topographic and hydrologic features, in Sonoma County, California.

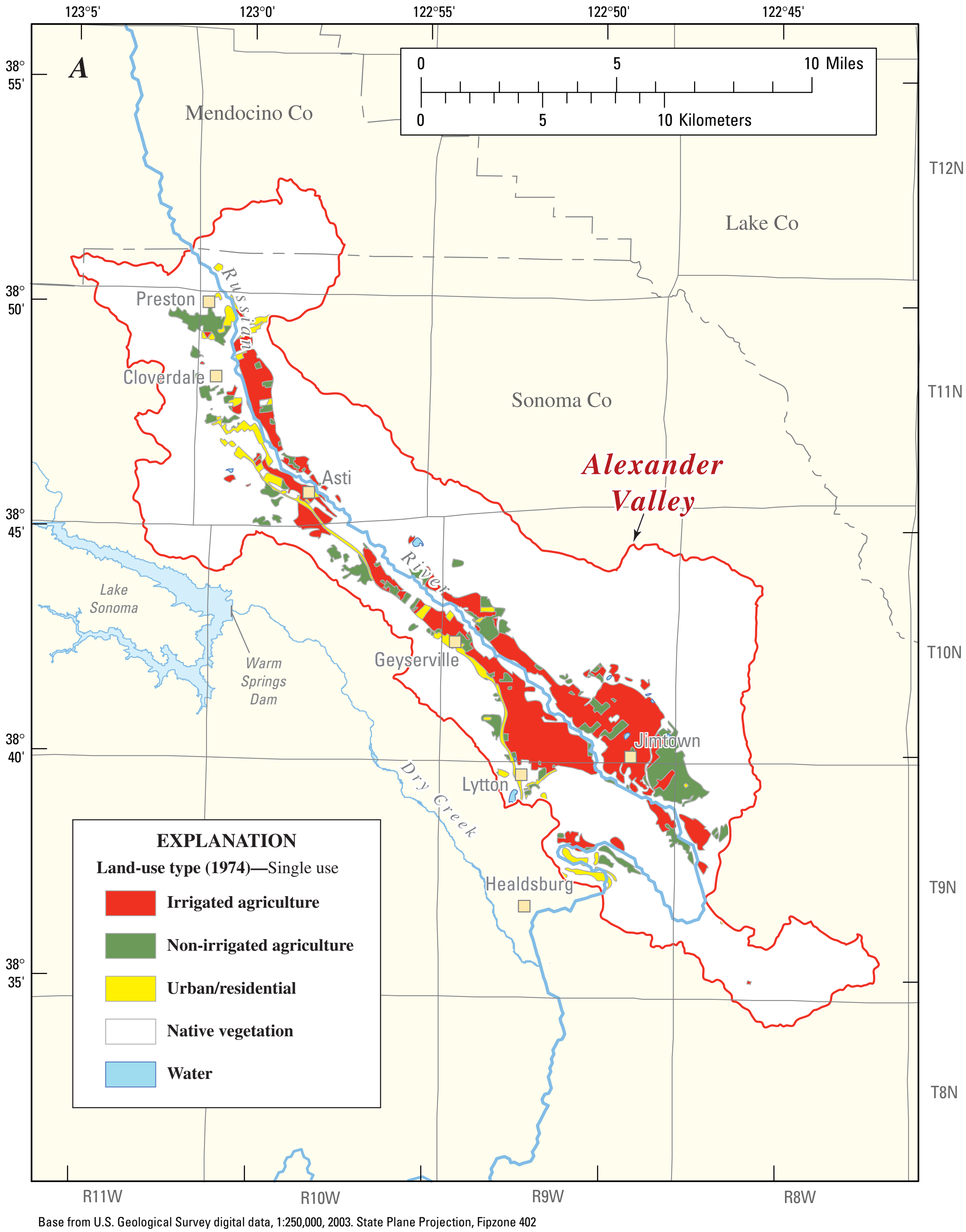
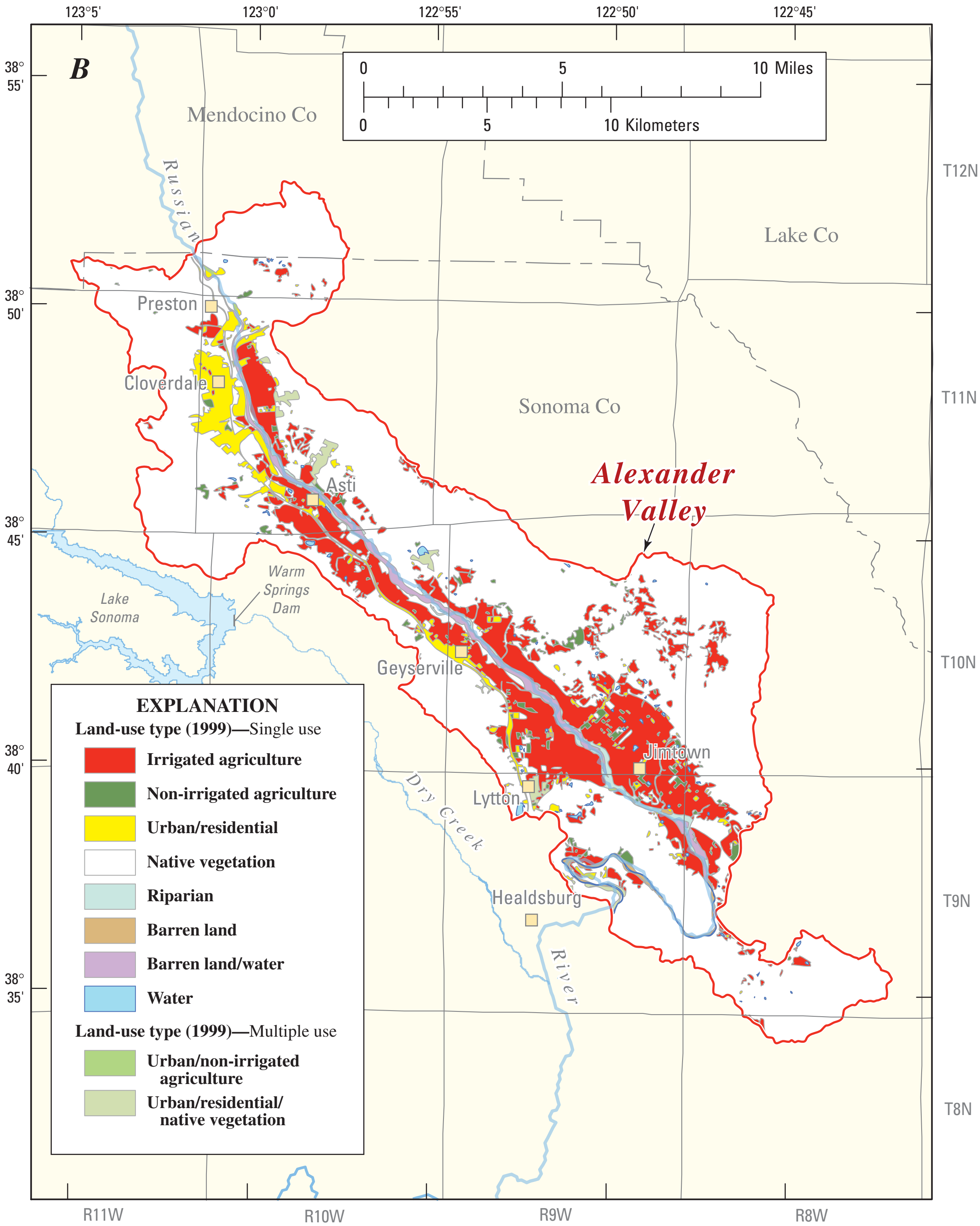


Figure 3. Land use in the Alexander Valley study area, Sonoma County, California. *A*, 1974; *B*, 1999. [Modified from land-use surveys of the California Department of Water Resources (1974, 1979)].



Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402

Figure 3.—Continued.

Table 1. Land use in Alexander Valley, Sonoma County California, 1974 and 1999.

[Because of rounding, all values may not add to totals; mi², square miles; NA, not applicable]

Land-use type	Land-use surveys[1] 1974 Acres	1974 mi²	1999 Acres	1999 mi²
Single use				
Irrigated agriculture (Including lawns)	8,618	13	14,465	23
Non-irrigated agriculture	3,616	6	1,114	2
Urban/residential (including commerical and industrial)	1,624	3	3,245	5
Native vegetation	67,497	105	59,227	92
Riparian	NA	NA	755	1
Barren	NA	NA	231	0
Barren/water	NA	NA	1,276	2
Water surface	87	0	327	0
Mixed use				
Urban/residential/non-irrigated agriculture	NA	NA	5	0
Urban/residential/native vegatation	NA	NA	654	1
Unknown designation	NA	NA	66	0
Total area	81,442	127	81,366	127

	1974 Percent of total area	1999 Percent of total area
Single use		
Native vegetation	83	73
Riparian	NA	1
Barren and barren/water	NA	2
Urban/residential (including commerical and industrial)	2	4
Total agriculture	15	19
Irrigated agriculture	11	18
Mixed use		
Urban/residential/non-irrigated agriculture	NA	0
Urban/residential/native vegatation	NA	1

[1]Modified from land-use surveys by the California Department of Water Resources, 1974, 1999.

Changes in land use between 1974 and 1999 were evaluated in this study (*fig. 3*, *table 1*; California Department of Water Resources, 1974 and 1999). In 1974, 83 percent of the land in the study area consisted of native vegetation; of the remaining 17 percent, 15 percent was for agricultural use and 2 percent was for urban and residential use. Agriculture was irrigated in 11 percent of the study area (*table 1*). By 1999, native vegetation in the study area declined to 73 percent. This was primarily due to the conversion of native lands to irrigated agriculture and urban and residential use. In 1999, mixed-use lands amounted to about 1 percent of the study area.

For the current study, the demand for irrigation water was estimated by multiplying crop acreages derived from California Department of Water Resources (CADWR) land-use surveys times the estimates, obtained from CADWR, of unit applied water (*table 2*; Scott Matyac, California Department of Water Resources, unpub. data, 2005). For this study, only one growing season per year was assumed for truck and field crops. Unit applied water is the total amount of water, in feet/year, estimated by CADWR to be delivered to a crop. Estimates of evapotranspiration of applied water were also obtained from CADWR (Scott Matyac, California Department of Water Resources, unpub. data, 2005). Irrigation efficiency is the ratio of evapotranspiration of applied water to unit applied water. In Alexander Valley, vineyards are the predominant crop type and are typically underwatered to stress plants to produce better grapes for wine production. Therefore, in Alexander Valley, the estimated irrigation efficiency for vineyards is about 89 percent; the other crops combined averaged about 72 percent irrigation efficiency (*table 2*).

In Alexander Valley, water demand for irrigation was estimated in this study to increase 43 percent from 9,400 acre-feet per year (acre-ft/yr) in 1974 to 13,500 acre-ft/yr in 1999, and irrigated agricultural fields increased by 68 percent, from 8,618 acres in 1974 to 14,465 acres in 1999 (*table 2*). The per-acre agricultural demand of water declined from 1974 to 1999 because farmers converted from higher water-consuming crops (pasture) to lower water-consuming crops (vineyards).

Water-use estimates (*table 2*) were evaluated against irrigation sources noted in parcels of the 1999 land-use survey (California Department of Water Resources, 1999). Of the estimated 13,500 acre-feet (acre-ft) of water used for irrigation in 1999, about 78 percent was met solely by ground water, about 6 percent was met solely by surface water, and about 1 percent was met by a combination of ground and surface water. About 15 percent of the estimated irrigation water had an unknown source of water. The areas irrigated solely by surface water were located primarily on the eastern bank of the Russian River at Cloverdale and in a limited area south of Jimtown. Areas of unknown water source adjacent to the Russian River south of Jimtown and east of Healdsburg likely used surface water diverted from the Russian River. Fields with unknown origin of irrigation water located on hillsides away from the Russian River were likely irrigated with ground water. It was assumed to be unlikely that water from the Russian River is being diverted significant distances.

By 2000, domestic water demand was estimated to be about 2,300 acre-ft/yr, based on an estimated population of 12,313 and an estimated domestic consumption of 0.19 acre-ft/yr per person (California Department of Water Resources, 1994). Most water for domestic use can be considered to be from ground water. However, many wells are located in proximity to the Russian River.

In summary, the estimated total water use for the Alexander Valley for 1999 was about 15,800 acre-ft (about 13,500 acre-ft for agriculture and about 2,300 acre-ft for domestic use), most of which was drawn from ground water. If one assumes that approximately 80 percent of agricultural use and 100 percent of domestic use is from ground water, then this equates to about 13,000 acre-ft of pumpage in 1999. This can be contrasted with Cardwell's (1965) estimate of 4,500 acre-ft/yr of pumpage in 1954.

From a water-rights perspective, water pumped from some wells near the river in the Alexander Valley may be legally considered as surface water drawn from the Russian River. However, this report does not consider water-rights definitions, only whether water is known to be pumped from a well.

Climate

The climate of the study area is Mediterranean, with moderate temperatures and distinct wet and dry seasons. Mean annual air temperature at Healdsburg is about 14.7°C and about 15.4°C at Cloverdale. Freezing temperatures on the valley floor are rare but do occur on the higher slopes of the bordering mountains. About 90 percent of the area's yearly precipitation falls from November through April. Nearly all the precipitation falls as rain. Mean annual precipitation at Healdsburg averaged about 42 inches (in.) for water years 1932 through 2004 (*table 3*) (National Oceanic and Atmospheric Administration, accessed December 19, 2005). As shown in *figure 4* and *table 3*, annual precipitation in any given year can deviate greatly from the 74-year average.

Table 2. Estimates of irrigated acreage by crop type, unit applied water, estimated annual applied water, and irrigation efficiency, Alexander Valley, Sonoma County, California, 1974 and 1999.

[ft/yr, feet per year; acre-ft/yr, acre-feet per year]

Crop class	Year					Irrigation efficiency
	Acres irrigated[1]		Unit applied water[2]	Estimated applied water[3] (acre-ft/yr)		
	1974	1999	(ft/yr)	1974	1999	(percent)
Citrus, deciduous, and field	703	188	2.0	1,406	376	75
Pasture and lawn	373	113	3.3	1,231	373	64
Grain	0	68	0.4	0	27	75
Truck	29	41	1.7	49	70	76
Vineyard	7,513	14,055	0.9	6,762	12,650	89
Totals	8,618	14,465		9,448	13,496	

[1]Estimated from California Department of Water Resources Crop surveys, California Department of Public Works (1974 and 1999).

[2]California Department of Water Resources (Scott Matyac, unpub. data, 2005).

[3]Applied water was estimated to be acreages multiplied by unit applied water.

Table 3. Precipitation at Healdsburg, Sonoma County, California, water years 1932–2004.

[Precipitation in inches. Data from National Oceanic & Atmospheric Administration website http://www1.ncdc.noaa.gov/pub/orders/110904743047dat.txt, Dec 19, 2005. *, missing values taken from reported values for alternate station: Russian River Near Healdsburg (HEA). Station data may be retrieved from the California Department of Water Resources, division of Flood Management, 2006, California Data Exchange Center (CDEC)—access point to the Department of Water Resources Operational Hydrologic Data: http: cdec.water.ca.gov/ (accessed January 2, 2006); **, estimated valued based on median rainfall for August for period of record]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Water year total
1932	1.89	3.19	15.59	3.05	1.91	1.14	1.71	1.83	0.03	0	0	0	30.34
1933	0.05	2.6	4.81	9.37	1.39	5.65	0.16	2.43	0	0	0	0.21	26.67
1934	2.07	0	14.67	1.42	8.14	1.2	0.92	1.57	1.12	0	0	0.08	31.19
1935	4.07	7.17	3.71	12.07	4.8	8.23	5.28	0.03	0	0	0.03	0.17	45.56
1936	1.44	1.83	5.19	8.59	13.54	1.76	2.58	1.05	1.34	0.12	0	0	37.44
1937	0.27	0.03	4.48	5.19	11.86	8.45	1.73	0.15	1.77	0	0	0	33.93
1938	1.34	9.74	9.49	8.14	13.47	10.67	2.79	0.03	0	0.01	0	0.41	56.09
1939	2.74	2.55	1.85	5.2	1.87	3	0.22	1.79	0	0	0	0.05	19.27
1940	0.23	0.72	7.07	17.12	20.68	7.07	1.88	1.84	0	0.02	0	0.42	57.05
1941	2.85	3.15	21.35	15.15	12.7	6.89	7.6	1.82	0.6	0	0.04	0.04	72.19
1942	2.54	5.14	12.38	10.42	10.11	4.01	7.05	3.12	0	0	0	0.1	54.87
1943	1.2	5.49	7.52	13.29	3.54	3.75	3.67	0	0.01	0	0	0	38.47
1944	1.43	1.68	3.43	7.56	8.9	2.87	2.9	2.83	0.21	0	0	0.02	31.83
1945	3.19	7.48	4.97	3.82	6.05	7.02	0.53	1.53	0	0	0	0	34.59
1946	6.71	6.7	14.84	2.49	4.06	1.89	0.1	0.5	0	0.18	0	0.07	37.54
1947	0.14	5.23	3.29	0.96	5.54	7.94	0.12	0.68	1.92	0	0	0	25.82
1948	6.54	1.06	2.11	3.75	1.55	6.43	12.93	1.23	0.42	0	0	0.09	36.11
1949	1.03	1.69	4.93	1.81	4.61	13.38	0.04	0.37	0	0.18	0**	0	28.04
1950	0.07	2.48	2.87	10.49	8.49	2.98	1.75	0.69	0.28	0	0	0	30.10
1951	6.04	8.13	10.73	6.2	3.86	1.23	1.33	2.55	0	0	0	0.01	40.08
1952	2.76	8.82	13.69	13.41	3.92	6.17	1.69	0.39	1.97	0	0	0	52.82
1953	0.07	3.7	19.93	10.97	0.1	4.23	4.77	1.25	0.66	0	0.45	0	46.13
1954	1.54	6.85	1	12.28	5.13	6.88	4.61	0.05	0.42	0.07	3.17	0	42.00
1955	1.45	8.44	7.61	3.84	1.33	0.62	5.76	0	0.01	0	0	0.33	29.39

Table 3. Precipitation at Healdsburg, Sonoma County, California, water years 1932–2004—Continued.

[Precipitation in inches. Data from National Oceanic & Atmospheric Administration website http://www1.ncdc.noaa.gov/pub/orders/110904743047dat.txt, Dec 19, 2005. *, missing values taken from reported values for alternate station: Russian River Near Healdsburg (HEA). Station data may be retrieved from the California Department of Water Resources, division of Flood Management, 2006, California Data Exchange Center (CDEC)—access point to the Department of Water Resources Operational Hydrologic Data: http: cdec.water.ca.gov/ (accessed January 2, 2006); **, estimated valued based on median rainfall for August for period of record]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Water year total
1956	0.47	4.58	22.34	16.62	9.05	0.31	2.9	0.84	0.05	0	0	0.12	57.28
1957	2.86	0.31	0.57	6.96	8.55	3	3.32	4.36	0.4	0	0	4.09	34.42
1958	8.77	1.17	5.28	10.04	23.34	9.64	6.5	0.3	0.85	0.09	0	0	65.98
1959	0.09	0.27	2.12	15.66	9.15	1.44	0.42	0.13	0	0	0	4.52	33.80
1960	0	0	2.04	9.27	10.45	5.95	1.49	1.12	0	0	0	0	30.32
1961	1.21	6.72	7.64	7.64	4.17	5.79	1.64	0.41	0.08	0	0.21	0.56	36.07
1962	0.29	6.8	3.79	1.88	16.91	7.13	0.4	0.14	0	0	0.3	0.26	37.90
1963	10.83	2.06	6.4	10.75	3.99	7.74	6.85	1.14	0	0	0	0.01	49.77
1964	3.14	12.09	1.26	5.74	0.22	2.68	0.26	0.62	0.46	0.03	0	0	26.50
1965	3.5	9.14	15.07	10.46	1.94	1.58	5.75	0	0	0.04	0.49	0	47.97
1966	0.11	12.42	6.61	11.33	6.29	1.34	1.25	0.13	0.05	0	0.11	0.11	39.75
1967	0	13.2	10.12	16.37	0.41	8.6	6.49	0.17	2.17	0	0	0.02	57.55
1968	1.14	3.47	5.89	10.96	6.59	4.89	1.44	0.23	0	0	0.86	0.03	35.50
1969	2.79	4.07	13.47	20.38	15.5	2.02	3.13	0.03	0	0	0	0.01	61.40
1970	2.71	1.56	18.58	25.24	5.2	2.63	0.12	0.02	0.45	0	0	0	56.51
1971	3.08	11.46	12.23	4.95	0.16	6	1.68	0.28	0	0	0.01	0.29	40.14
1972	0.43	3	7.77	2.02	2.92	1.23	3.12	0.13	0.06	0	0	0.67	21.35
1973	4.17	9.89	5.32	18.39	9.54	3.83	0.15	0.03	0	0	0	0.75	52.07
1974	4.79	21.2	6.65	10.67	5.21	12.17	2.07	0.15	0	1.71	0	0	64.62
1975	1.77	1.96	7.5	2.72	13.86	11.33	1.73	0	0.01	0.21	0.04	0	41.13
1976	5.62	1.43	1.92	0.41	2.93	1.01	3.24	0	0	0.03	1.12	0.56	18.27
1977	0.42	2.78	1.17	2.53	2.74	2.38	0.35	1.77	0	0	0	2.78	16.92
1978	1.1	8.48	9	19.14	9.79	7.45	4.44	0.15	0	0	0	2.21	61.76
1979	0	1.49	0.49	10.99	11.71	3.25	2.39	0.92	0	0	0	0.11	31.35
1980	4.98	7.08	10.75	8.82	14.61	1.79	3.06	0.36	0.27	0.04	0	0	51.76
1981	0.57	0.62	11.23	10.78	3.92	4.62	0.36	0.62	0	0.07	0	0.46	33.25

Table 3. Precipitation at Healdsburg, Sonoma County, California, water years 1932–2004—Continued.

[Precipitation in inches. Data from National Oceanic & Atmospheric Administration website http://www1.ncdc.noaa.gov/pub/orders/110904743047dat.txt, Dec 19, 2005. *, missing values taken from reported values for alternate station: Russian River Near Healdsburg (HEA). Station data may be retrieved from the California Department of Water Resources, division of Flood Management, 2006, California Data Exchange Center (CDEC)—access point to the Department of Water Resources Operational Hydrologic Data: http: cdec.water.ca.gov/ (accessed January 2, 2006); **, estimated valued based on median rainfall for August for period of record]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Water year total
1982	4.66	13.34	13.06	9.03	6.51	9.41	7.2	0	0.04	0	0	0.87	64.12
1983	5.05	9.47	8.58	15.7	14.84	20.34	6.31	0.86	0	0	1.52	0.59	83.26
1984	1.15	17.57	17.37	0.86	3.07	3.97	1.58	0.2	0.22	0	0.2	0.06	46.25
1985	2.37	15.44	2.43	1.35	3.4	7.31	0.28	0	0	0.05	0	1.37	34.00
1986	1.65	4.92	4.98	9.89	21.95	9.24	0.98	0.46	0	0	0	1.95	56.02
1987	0.64	0.15	2.95	6.25	6.47	8.53	0.2	0.1	0	0	0	0	25.29
1988	2.65	4.92	11.54	9.16	0.65	0.07	2.58	0.75	0.25	0	0	0	32.57
1989	0.41	5.92	4.53	1.5	1.21	12.01	1.75	0.19	0.45	0	0	2.98	30.95
1990	4.47	1.97	0	7.08	4	1.81	0.21	6.44	0	0	0	0.2	26.18
1991	0.77	0.38	1.33	1.1	5.26	18.35	0.47	0.25	0.63	0	0.02	0	28.56
1992	0.82	2.03	4.43	2.83	12.86	5.89	1.84	0	0.8	0	0	0	31.50
1993	3.64	0.43	12.25	15.23	9.43	3.29	2.58	2.31	0.97	0	0	0	50.13
1994	0.97	3.42	6.62	4.39	7.58	0.68	2.43	0.98	0	0	0	0	27.07
1995	0.98	9.54	5.36	29.9	0.36	20.01	3.31	1.54	0.38	0	0	0	71.38
1996	0.03	0.4	12.63	9.97	14.14	3.23	3.34	3.12	0	0	0	0.02	46.88
1997	2.29	4.68	17.21	14.43	0.43	2.46	1.01	0.8	0.59	0	1.05	0.4	45.35
1998	1.26	11.59	4.09	15.38	25.41	4.61	3.21	7.52	0.03	0	0	0.09	73.19
1999	1.37	8.88	1.62	5.06*	12.88	6.62	2.31	0.04	0.06	0	0	0.07	33.85
2000	1.19	6.98	0.99	9.61	14.58	3.15	3.09	1.83	0.26	0	0**	0.13	41.81
2001	3.44	1.25	1.12	7.97	9.77	2.94	1.4	0	0.04	0	0	0.21	28.14
2002	3.03	10.44	12.83	3.08	1.8	3.46	0.51	1.58	0	0	0	0	36.73
2003	0	5.16	25.21	6.5	2.8	4.84	6.55	1.19	0	0.04	0	0.01	52.30
2004	0*	4.06	18.81	5.75	12.82	1.79	1.55	0.08	0	0	0	0.05	44.91
Max.	10.83	21.20	25.21	29.90	25.41	20.34	12.93	7.52	2.17	1.71	3.17	4.52	83.26
Min.	0.00	0.00	0.00	0.41	0.10	0.07	0.04	0.00	0.00	0.00	0.00	0.00	16.92
Mean	2.18	5.40	7.98	8.89	7.52	5.44	2.62	0.99	0.28	0.04	0.14	0.39	41.87

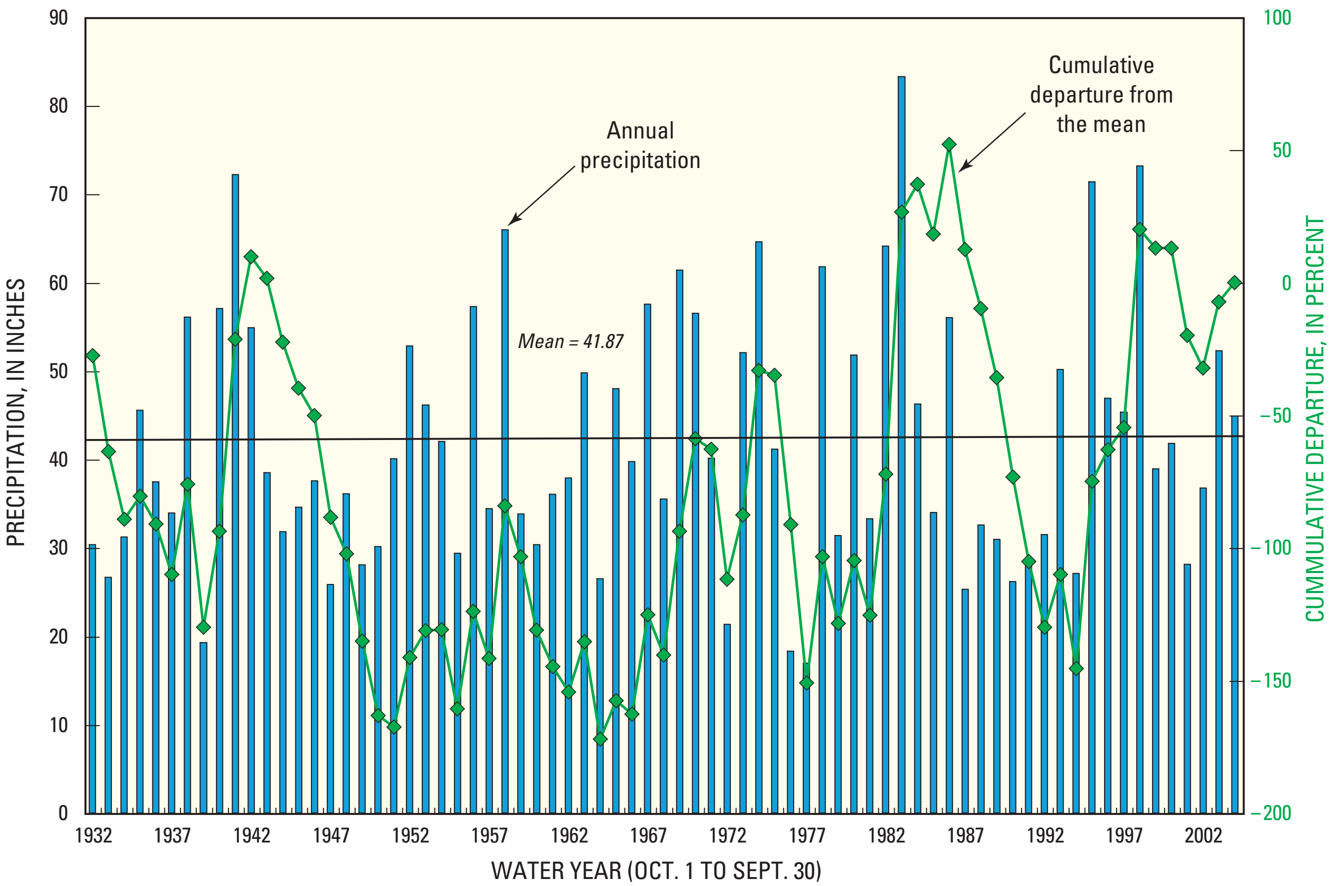


Figure 4. Annual precipitation, and cumulative departure from the mean of precipitation, at Healdsburg, Sonoma County, California, 1932–2004.

The average precipitation for the study area was computed for water years 1952–2004 using the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) of Daly and others (1994) and monthly precipitation data from the Oregon State University Spatial Climate Analysis Service (accessed January 13, 2006). PRISM is designed to map climate in complex environmental regimes, including high mountainous terrain and rain shadows (Daly and others, 1994). PRISM uses point measurements, digital elevation models, and other spatial data to generate gridded estimates of monthly and yearly precipitation. PRISM fits separate precipitation/altitude relations to neighboring stations with the same topographic aspect to generate interpolated values. This is a departure from simply applying a single altitude-dependent precipitation measurement to similar altitudes within the basin. Thus, PRISM is automated to adjust its frame of reference to accommodate local and regional climatic differences, rain shadows and coastal effects to create a pattern of precipitation (Daly and others, 1994). Average precipitation for the study area for water years 1952–2004 is 44 in.

Previous Investigations and Data Bases

Weaver (1949) carried out one of the earliest comprehensive geologic investigations that included the study area. His work defined the basic geology of the area in terms of stratigraphy and structure. A more detailed description of the geology of the southern part of the study area is given by Fox and others (1985).

The geographic area of the current study was included in a comprehensive hydrogeologic investigation of the Russian River Valley by the U.S. Geological Survey (Cardwell, 1965). Cardwell's data and interpretation have provided a foundation for later hydrologic studies. The ground-water resources of Sonoma County, including Alexander Valley, are described in a report by the California Department of Water Resources (1975). In the early 1980s, the California Department of Water Resources carried out a more detailed study focused solely on Alexander Valley and the Healdsburg area (California Department of Water Resources, 1983). The CADWR study estimated storage capacities for the area of the valley underlain by alluvial units, showed changes in ground-water levels between the 1960s and 1980, and described the quality of ground water.

The SCWA developed a geographic information system (GIS) for Alexander Valley. The USGS has built on this database. The current working database includes: geology; soils; surface hydrology; digital elevation information describing slope, aspect, and altitudes; climate data; water-well location and construction data; surface-water gaging station information; public water supply service areas; septic, wastewater treatment, and reclaimed-water delivery systems; landfills; historical land use; roads; pipelines; a census population map; public land survey system delineations; and land ownership parcel information. The GIS was used to manage spatial data, to compute supporting data for this study, and to characterize the study area in terms of land-use water-demand categories, ground- and surface-water quality, ground-water levels, topography, altitudes, geology, and the distribution of precipitation and runoff.

Acknowledgments

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Physiography and Geologic Setting

The Alexander Valley study area is located in the North Coast Ranges geomorphic province of California. This province is characterized by a strong northwest-trending topography (Page, 1966). The mountain ranges are underlain by thick, highly deformed Mesozoic sedimentary strata that in places are covered by younger volcanic and sedimentary rocks. The mountains commonly have a hummocky, irregular topography produced in part by deep-seated landslides and shallow debris- and earth-flows (McLaughlin and others, 2005). The core of the North Coast Ranges consists of three major pre-Tertiary rock groups: the Franciscan Complex, the Coast Range Ophiolite, and the Great Valley Sequence (Blake and others, 2000) (*fig. 5*). In the eastern and northern parts of the Alexander Valley watershed, exposed basement rocks are predominantly Franciscan Complex but include a few minor outcrops of Coast Range Ophiolite. The Great Valley Sequence crops out in the hills along the western side of the watershed (Blake and others, 2002). All three pre-Tertiary rock groups, which overlap in age, were tectonically transported from a marine basin in the Pacific Ocean and accreted to the continental margin of California during Cretaceous to early Tertiary time (Blake and others, 2000). During and after accretion the rocks were folded and faulted into mountain ranges and intervening valleys. Within the study area, several northwest trending faults have been mapped in the Mayacmas Mountains and in the hills along the southwestern part of the area (*fig. 5*). The faults in the Mayacmas Mountains are part of the Maacama Fault Zone and the faults along the western side of the study area are part of the Rodgers Creek–Healdsburg Fault zone (Blake and others, 2002). These faults are related regionally to the San Andreas Fault system.

Within the study area, the mountains are of moderate relief, sloping gently toward the valley from mountain crests; altitudes are mostly between 400 and 1,000 feet (ft). The mountainsides commonly exhibit a subdued topography of rolling grass- and oak-covered slopes and swales. Parts of the Franciscan Complex have eroded to form resistant blocks ranging from a few feet to miles in the long dimension embedded in a soft matrix that forms intervening slopes of moderate relief (McLaughlin and others, 2005).

The northwest-trending elongate depression of Alexander Valley extends roughly 20 mi from near Healdsburg to the county line north of Cloverdale (*fig. 2*). The valley floor has a maximum width of about 4 mi and averages about 1.5 mi wide. The valley can be subdivided into two parts on the basis of topography. The northern part of the valley, which includes Cloverdale, extends about 6 mi southeastward from the county line to about 1 mi southeast of Asti, and is sometimes referred to as Cloverdale Valley. The flood plain is less than 2 mi wide and bordered by low terraces near Cloverdale. The valley narrows to less than 0.5 mi near Asti. The southern part of the valley extends for about 14 mi southeastward from the narrows near Asti. Near the southern end, the valley floor widens to about 4 mi. The Russian River leaves the southern end of the valley through a narrow and sinuous canyon. The course of the Russian River is probably controlled, in part, by the northwest trending Maacama Fault Zone. Over the full length of the valley, altitudes along the Russian River drop from 400 ft at the north end to about 100 ft at the south end.

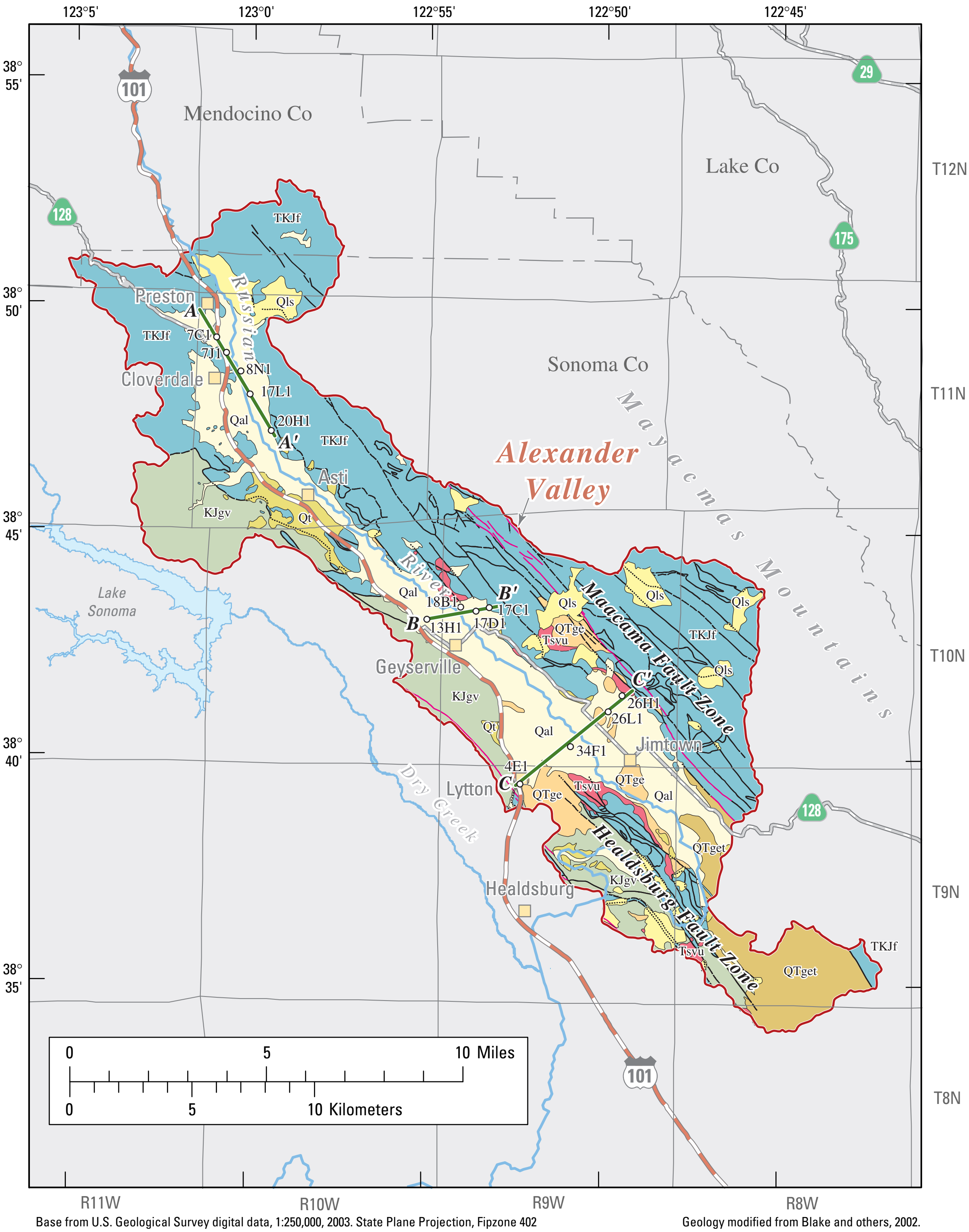


Figure 5. Geologic map of the Alexander Valley watershed, Sonoma County, California.

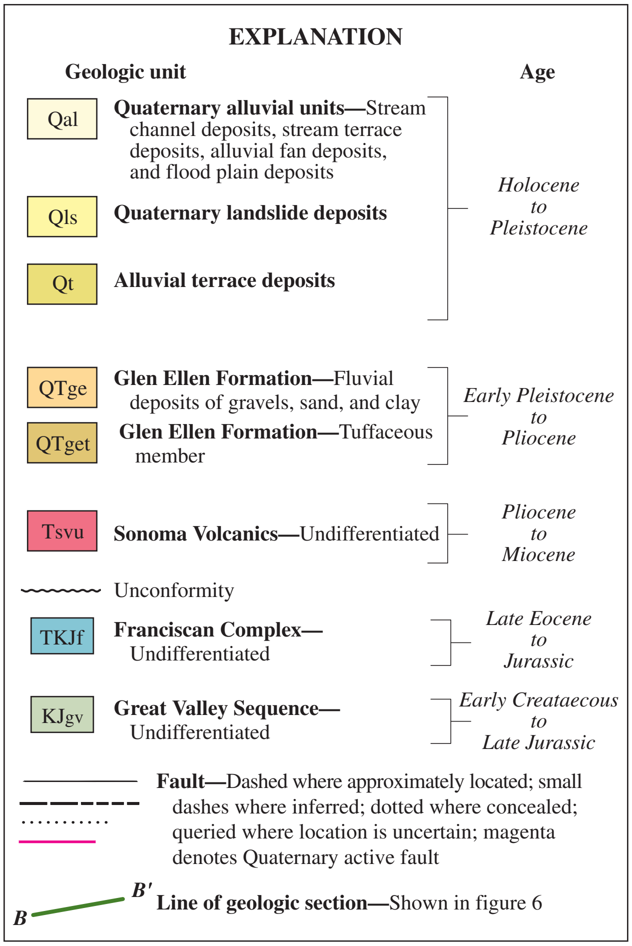


Figure 5.—Continued.

Geology

The stratigraphy of the study area described here is based on the recent compilation of the regional geology by Blake and others (2002). The geologic units shown for the study area conform to the most recent stratigraphic nomenclature. The geology of Blake and others (2002) is similar to that shown in Cardwell (1965) and California Department of Water Resources (1983). The main differences are that the recent mapping subdivides the Franciscan Complex into a greater number of lithologic units, the Coast Range Ophiolite is delineated, and the Glen Ellen Formation is subdivided to show the outcrops of the tuffaceous member. The entire watershed is underlain by basement rocks comprised of Franciscan Complex, Coast Range Ophiolite, and Great Valley Sequence, which are overlain by younger volcanic and sedimentary rocks and unconsolidated sediments (*fig. 5*).

Basement Rocks

The Franciscan Complex, as the name implies, includes rocks of several different lithologies; they include sandstone, graywacke, shale, mélange, conglomerate, chert, greenstone, and serpentinite (Bailey and others, 1964). These rocks, originally deposited in marine basins during Jurassic to Cretaceous time, have become highly indurated through the processes of compaction and secondary mineralization (Blake and Jones, 1981). Most of the rocks are weakly to strongly metamorphosed, having been deeply buried and subjected to elevated temperatures during a period of millions of years.

Rocks of the Franciscan Complex are exposed over much of the northern and eastern parts of the watershed and probably underlie much of the valley floor (*fig. 5*). The thickness is unknown but undoubtedly is a few tens of thousands of feet (Blake and others, 2000). Porosity and permeability are very low in Franciscan rocks because most of the original pore spaces are filled by minerals that cement the individual grains together. Most of the modern permeability resulted from fractures that developed in response to the deformation of the various rock packages as they were transported from the sea floor to the continent. Because of the low permeability and specific storage capacity, Franciscan rocks commonly are considered to be non-water bearing and to form the boundaries of ground-water basins throughout the Coast Ranges (California Department of Water Resources, 1958).

Exposures of Coast Range Ophiolite in the Mayacmas Mountains have been mapped as small outcrops within larger masses of Franciscan Complex (Blake and others, 2002). The Ophiolite consists of serpentinized peridotite, gabbro, and basalt that has been faulted and tectonically interleaved with the Franciscan Complex (McLaughlin and others, 2005).

The Great Valley Sequence is exposed in the hills along the western side of the study area and probably extends beneath parts of the adjacent valley floor. Great Valley Sequence rocks are mostly sandstone, shale, and conglomerate units. A distinctive unit, informally named the Dry Creek Conglomerate, was mapped by Blake and others (2002) along a 10-mi-long outcrop area that extends northwestward from near Lytton. This unit consists of well-rounded cobbles and boulders, mostly derived from the Franciscan Complex, in a sand matrix. The total thickness of the Dry Creek Conglomerate was estimated to be about 5,000 ft (Gealey, 1951). Most of the Great Valley Sequence rocks are typically well-cemented and indurated. Wells drilled in these rocks generally yield little or no water (Kunkel and Upson, 1960; Page, 1986).

Basin Fill

The basin is filled with younger rocks and sediments deposited unconformably upon basement rocks. The basin fill material includes the Sonoma Volcanics, the Glen Ellen Formation, and Quaternary alluvial units (*fig. 6A–C*). Landslide deposits have been mapped in the hills adjacent to the valley floor (*fig. 3*).

Sonoma Volcanics

The Sonoma Volcanics are of Miocene to Pliocene age and are widely distributed throughout Napa and Sonoma Counties (Weaver, 1949). The Sonoma Volcanics are exposed in a few small outcrops in the southern part of the study area where they lie unconformably on rocks of the Franciscan Complex or of the Great Valley Sequence (*fig. 5*). The Sonoma Volcanics were first described by Osmont (1905). The geologic unit is a thick, highly variable sequence of continental volcanic and volcaniclastic rocks including basalt, andesite, and rhyolite lavas interbedded with tuffs, lahar deposits, avalanche deposits, mudflow units, hyaloclastites, reworked tuffs, sedimentary deposits derived from volcanic rocks, and lacustrine deposits.

Although exposures of the Sonoma Volcanics are quite limited in the study area, a great deal is known about its lithologic characteristics from observations made in nearby locations. The Sonoma Volcanics were produced by a complex eruptive history of the many vents in the study area; the vents, which varied in chemical composition, produced lava flows, dikes, plugs, breccias, pumice beds, welded tuff layers, and debris flows (McLaughlin and others, 2005). Many individual units show lenticular form in cross section. Most lava flows are from a few feet to a few tens of feet thick. In places these rocks are strongly folded or broken by faults. Kunkel and Upson (1960) divided the unit into three members: a basal member of mostly basalt and andesite lavas interbedded with tuff units; a diatomite member; and an upper member consisting mostly of rhyolite lavas and tuffs, often welded. The Sonoma Volcanics are overlain by the Glen Ellen Formation; however, in places the upper part of the Sonoma Volcanics may interfinger with the Glen Ellen Formation (Cardwell, 1965; Blake and others, 2002). In locations around the valley margin, where the Glen Ellen Formation has eroded away, the Sonoma Volcanics are overlain unconformably by Quaternary alluvial units (*fig. 5*).

Glen Ellen Formation

The Glen Ellen Formation was first described by Weaver (1949) for continental deposits that crop out near Glen Ellen in Sonoma Valley. The assignment of sedimentary strata in Alexander Valley to the Glen Ellen Formation is based on chronostratigraphic relations to the Sonoma Volcanics (McLaughlin and others, 2005). The sedimentary rocks making up the Glen Ellen Formation were probably originally deposited as alluvial fans and piedmont. The formation is widely exposed in the southern part of the study area and is estimated to be about 1,500 ft thick in outcrops along the east side of the valley (Cardwell, 1965). The formation underlies much of the valley floor south of Geyserville and may underlie the valley floor in places between Geyserville and Asti. The formation is largely of fluvial origin and consists of clay-rich stratified deposits of poorly sorted sand, silt, and gravel interbedded with minor beds of matrix-supported conglomerate and silicic tuffs (Cardwell, 1965). Beds grade from coarse- to fine-grained laterally and vertically, commonly over distances of a few tens to a few hundreds of feet. Bedding is thick to massive and often lenticular in form. Most of the clasts and probably much of the matrix were derived from the Sonoma Volcanics. Cobbles in the conglomerates are mostly subangular to rounded and, for the most part, range between 3 and 6 in. in diameter. The cobbles are mostly of andesitic or basaltic composition and include obsidian clasts that are characteristic of this formation (Cardwell, 1965). In some areas, the Glen Ellen Formation consists primarily of tuffaceous material (QTget) reworked by streams. This differentiated material occurs in the southern part of the study area (*fig. 5*).

Stratigraphic relations indicate that the Glen Ellen Formation is of late Pliocene to early Pleistocene age (Blake and others, 2002). The formation overlies tuff in the Sonoma Volcanics dated at 3.1 million years before present (ma) ; the upper part of the formation contains tephra dated at 1.2 to 0.8 ma (McLaughlin and others, 2005). Within parts of the study area, the Glen Ellen Formation is in fault contact with, or rests unconformably upon, rocks of the Franciscan Complex but in other parts of the area laps onto the Sonoma Volcanics (*fig. 5*). Along the valley floor, the Glen Ellen Formation is overlain by alluvial units of Quaternary age.

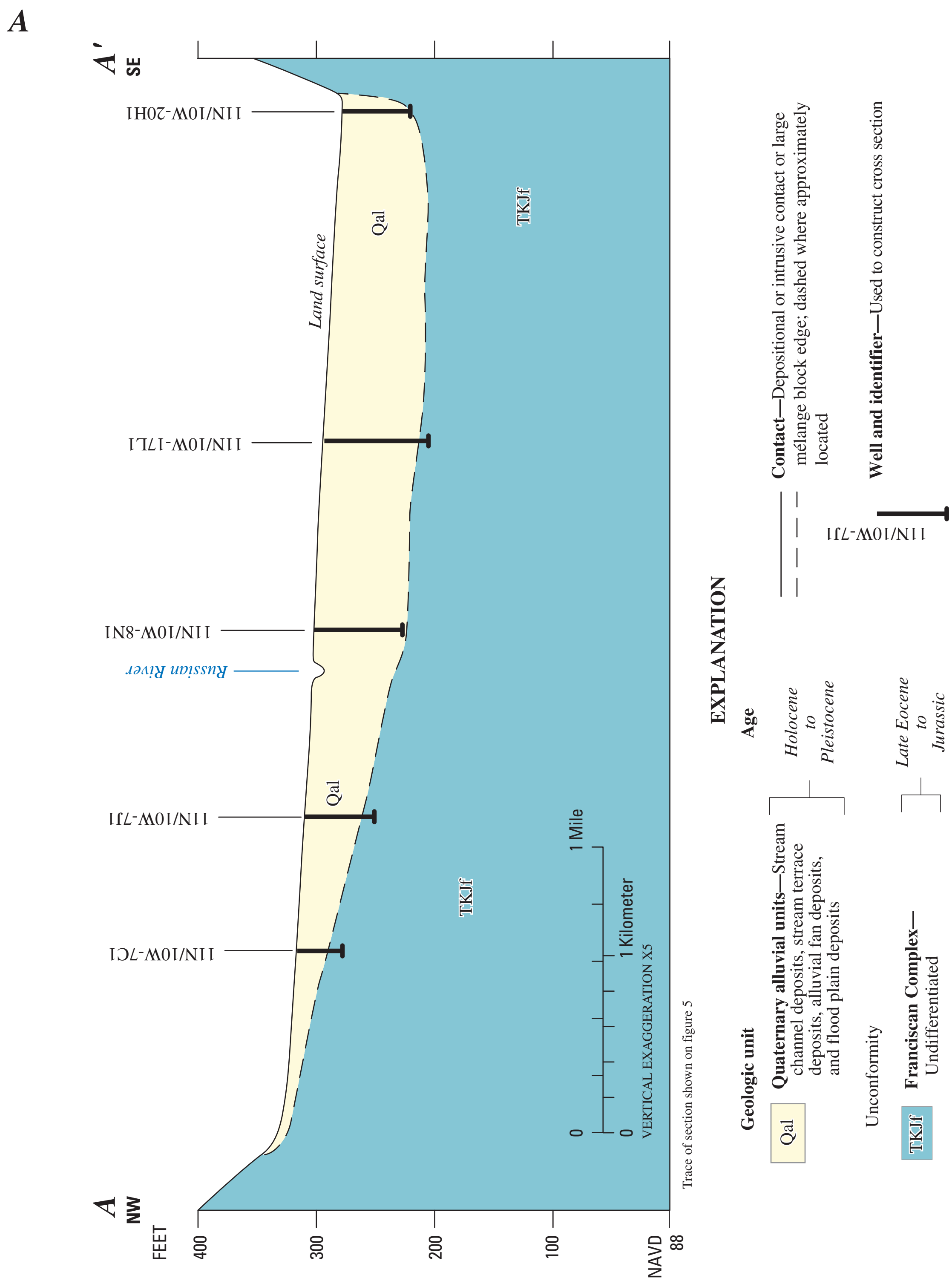


Figure 6. Geologic cross sections of the Alexander Valley watershed, Sonoma County, California. See figure 5 for location of sections.

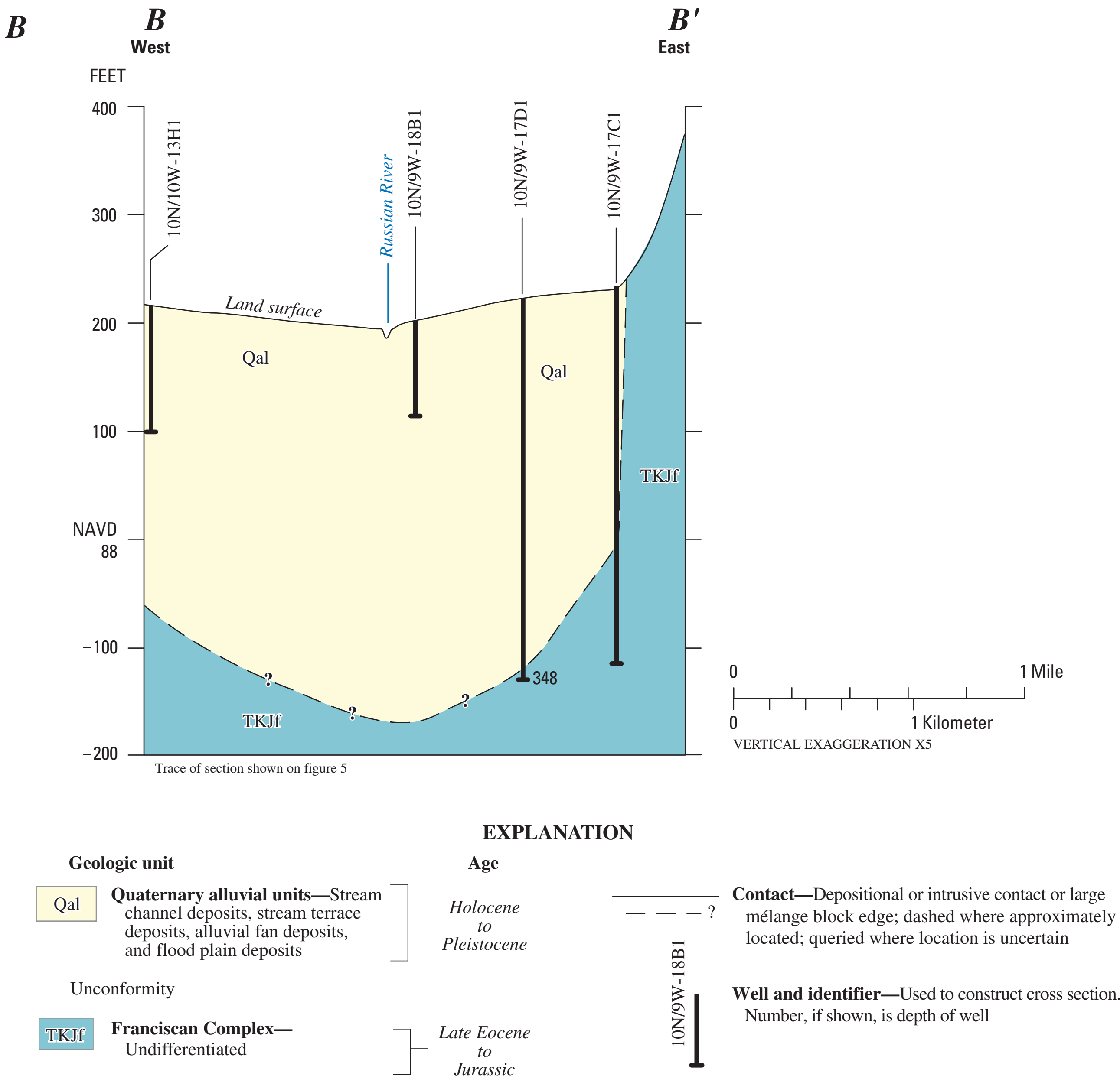


Figure 6.—Continued.

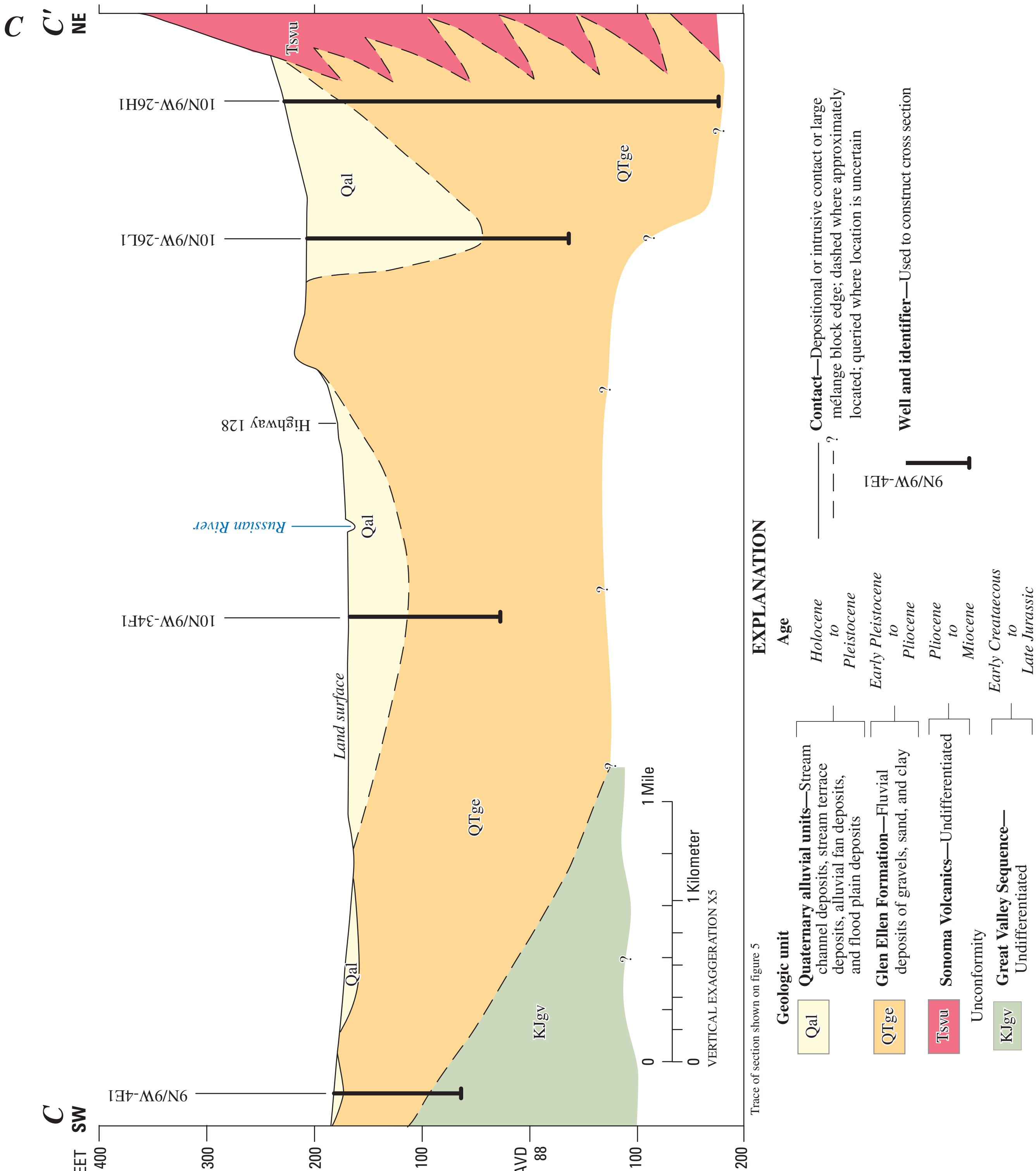


Figure 6.—Continued.

Quaternary Alluvial Units

The alluvial sediments of Quaternary age have been mapped by various investigators (Cardwell, 1965) as river channel deposits, alluvium, and terrace deposits, on the basis of the degree of consolidation, cementation, clast size and sorting, and geomorphic expression. In this report the alluvial units are not differentiated. The alluvial units cover about 24 mi^2 of the watershed and form a band covering the main part of the valley floor from north of Cloverdale to south of Jimtown (*fig. 5*) The alluvial units consist of poorly consolidated to unconsolidated clastic materials ranging from clay size to boulders. The deposits, depending on mode of origin, are wedge-shaped, lens-shaped, or channel-shaped. Sorting within a particular unit depends on the distance from source materials, the type of source materials, and the hydraulic energy of the transporting medium. Data from drillers' logs indicate that the alluvial materials nearest the valley axis generally contain the greatest proportions of course clasts and generally are better sorted than deposits closer to the mountain flanks. The logs also show that the greatest thicknesses of coarse-grained materials are beneath the central axis of the valley and in the southern part of the valley where thicknesses are as much as 80 ft. Near the present-day course of the Russian River and near some of the larger tributaries, stream channel deposits consisting of boulders, cobbles, gravel, and sand form thin sinuous bodies within more poorly sorted, finer grained sediments deposited on flood plains. The channel deposits tend to be thin and discontinuous owing to shifting channel locations over time.

Quaternary Landslides

Landslides have been mapped in the hills adjacent to the eastside of the valley (Blake and others, 2002). The landslides are composed mostly of material derived from the Franciscan Complex. The material consists of poorly sorted boulders and smaller clasts embedded in a matrix of finer grained particles. Some of the vegetation that had been growing in the slide area before sliding began was incorporated into the slide mass as it moved down slope. Most of the landslides are probably relatively thin, on the order of 100 ft or less. The slide areas often have a hummocky topography and may include areas of poor drainage.

Geologic Structures

Alexander Valley is a fault-controlled structure that lies between the Maacama Fault Zone and the Healdsburg Fault Zone (Blake and others, 2002), two major northwest-striking faults in the northern Coast Ranges (*fig. 5*). Both faults have had large components of right-lateral strike-slip movement but also have had compressional slip normal to the strike. The fault geometry and strike-slip movement results in the formation of depressions along zones of oblique pull-apart extension between the faults (McLaughlin and others, 2005). Ukiah Valley and Little Lake Valley to the north of the study area are recognized as sediment-filled pull-apart basins (McLaughlin and Nilsen, 1982); Alexander Valley likely has a similar origin. The later compressional component of slip on the faults has caused folding in the Sonoma Volcanics and the Glen Ellen Formation. The folding is especially evident in the southern part of the study area where beds of the tuffaceous member of the Glen Ellen Formation dip away from outcrops of the Franciscan Complex. Dips are generally 30 degrees or less but, in places are more than 50 degrees and appear to define an anticlinal structure.

Hydrology

Surface-Water Hydrology

The headwaters of the Russian River are in Mendocino County where the east fork of the Russian River has been dammed to create Lake Mendocino, a reservoir for public water supply and recreation (*fig. 1*). The Russian River enters the study area through a bedrock narrow near the Mendocino-Sonoma County line and continues its course of about 36 mi to where it exits the study area on the southwestern side. The river surface drops with a fairly constant gradient of about 9 feet per mile (ft/mi) from the county line to Healdsburg.

Since 1959, discharge in the Russian River has been strongly affected by the controlled releases of water from Coyote Valley Dam, which created Lake Mendocino (*fig. 7*), located north of the study area in Mendocino County. The reservoir is operated by the U.S. Army Corps of Engineers to provide flood control and water-supply storage of 118,000 acre-ft. The Sonoma County Water Agency and the Mendocino County Russian River Flood Control and Water Conservation Improvement District share appropriative water rights to store and use water in the reservoir. The Sonoma County Water Agency has sole rights to determine the releases from the water-supply pool.

Discharge in the Russian River is gaged by the USGS at a point about 5.5 mi northwest of Cloverdale (USGS Station 11463000), upstream of the study area boundary, and at a second location about 2 mi east of Healdsburg (USGS Station 11464000), near the southern end of the study area (*fig. 7*). The approximate drainage area between the two gages is 290 mi^2, which includes about 163 mi^2 outside of the study area (*fig. 7*). The maximum daily discharge measured at the gage near Healdsburg (period of record: 1939 to 2004) was 69,300 cubic feet per second (ft^3/s) on January 9, 1995, and the minimum was 12 ft^3/s on June 14, 1988 (Webster and others, 2005).

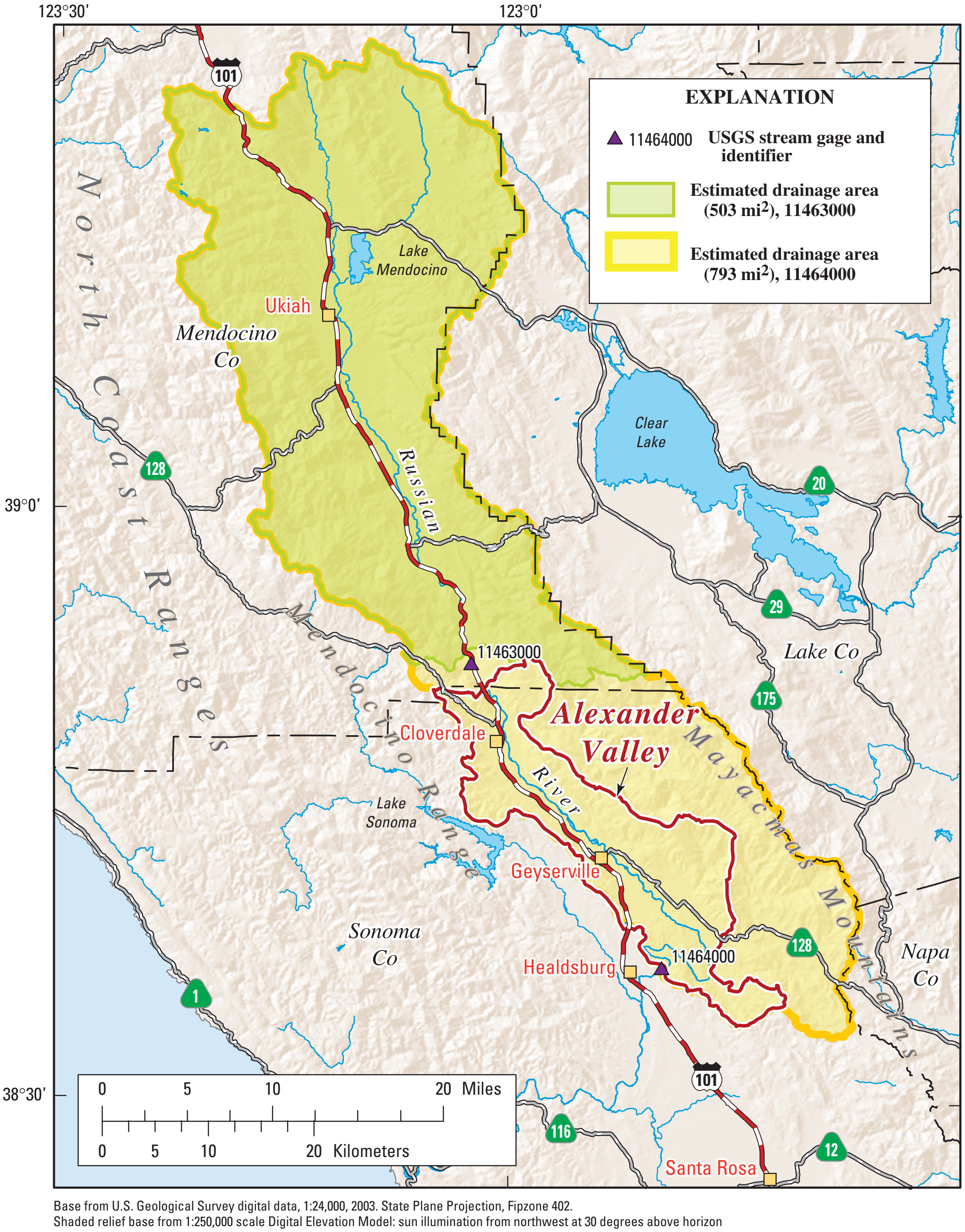


Figure 7. Drainage areas for USGS streamflow-gaging stations 11463000 and 11464000 in Alexander Valley, Sonoma County, California.

In most water years, discharge to the Russian River in response to the normal annual cycle of precipitation does not increase markedly until November or December; it then decreases rapidly in April or May (*figs. 8A and 8B*). A period of 10 years is shown in *figures 8A and 8B*, rather than the full period of record to allow the annual cycles of discharge to be seen more clearly. Discharge from the Russian River remains relatively constant through late summer and early autumn and does not increase significantly until about 10 to 12 in. of precipitation has fallen at Healdsburg. This amount of precipitation represents the soil-moisture deficit that develops from evapotranspiration during the dry season, which runs from late spring to late autumn in most years. Streamflow does not increase significantly until the soil moisture increases to near field capacity. Similar soil-moisture deficits have been estimated for Sonoma Valley and parts of Napa Valley (Johnson, 1977; Farrar and others, 2006).

The difference in discharge between the gage near Cloverdale (11463000) and the gage near Healdsburg (11464000) (*figs. 8C–E*) offers insights into ground-water/surface-water interaction. The difference in discharge is dependent on the amount of additional water entering the Russian River from tributaries between the two gages, the amount of water used by evapotranspiration in the riparian zone, diversions, and ground-water recharge. Graphs showing the difference in discharge between the two gages are shown for 3 selected water years: 1977, 1995, and 2000. The 3 years represent a drought year, a wet year, and a near-normal year, respectively, in terms of annual total precipitation. As shown in figure 4, precipitation varies greatly from year to year; there is virtually no year that has exactly the mean preciptation. These comparisons of daily discharge values do not account for travel times between the gages. This is not considered significant for the analysis of seasonal trends.

Discharge at the downstream gage (near Healdsburg) generally first decreases in June or July to below that discharged at the upstream gage (near Cloverdale). A decrease in discharge tends to occur later following very wet winter seasons and earlier in years of below average precipitation. Following winters having above average precipitation (for example 1995), tributaries contribute water to the Russian River later into the dry season than during years with below average precipitation. Also, soil-moisture remains higher later into the dry season and therefore less irrigation for crops is required, which reduces the amount of river water diverted. These factors account for the greater discharge at the downstream gage than at the upstream gage. As the summer progresses, greater amounts of water are diverted from the Russian River, pumping from wells near the river increases, and riparian vegetation consumes greater amounts of underflow and shallow ground water through evaptranspriation. This causes a decrease in discharge between the two gages. In dry years (for example, 1977), soil moisture may not be completely replenished before the rains stop. Consequently, irrigation will begin earlier in the spring or summer, which will result in a depletion of discharge in the Russian River between the two gages earlier in the year.

Water year 2000 represents a near normal year in terms of precipitation; with 41.57 in. measured at Healdsburg compared with an average precipitation of 41.87 in. for 1932–2004. Discharge at the Healdsburg gage was greater than that at the Cloverdale gage between February and June 17, 2000, (except for 1 day) primarily because of inflow from tributaries downstream of the Cloverdale gage. After June 17, discharge decreased between Cloverdale and Healdsburg on most days; this pattern persisted until October 25, when discharge began to increase consistently between the two gages. The decrease in discharge is a measure of evapotranspiration along the riparian corridor, direct diversions from the river, indirect diversions from ground-water pumping near the river, and seepage from the river into the alluvial aquifer. The total difference in discharge between the two gages from June 17 to October 25, 2000 was about 2,776 acre-ft. This represents the minimum amount of water consumed between the two gages; additional water may have entered the river from tributaries or from irrigation return. However, these quantities were not gaged.

Geohydrology

Ground water in the Alexander Valley watershed is contained in all the geologic formations and alluvial deposits present (*figs. 5* and *6*). However, the water-bearing properties of the various geologic units vary considerably and largely determine how much water can be obtained from a well in different parts of the watershed. Most wells in the study area are drilled to depths of less than 200 ft. On the basis of data on 350 wells provided by the CADWR, the median well depth is 102 ft. The main sources of ground-water recharge in the study area are direct infiltration of local precipitation that falls on the mountains and valley floor and infiltration of surface water from the Russian River and its tributaries. Excess irrigation water, originally derived from streams or ground water, probably provides additional ground-water recharge.

The primary sources of ground water in the study area are the Quaternary alluvial deposits, the Glen Ellen Formation, and the Sonoma Volcanics. All these geologic units have a wide distribution and zones of high porosity (greater than 20 percent) and high permeability.

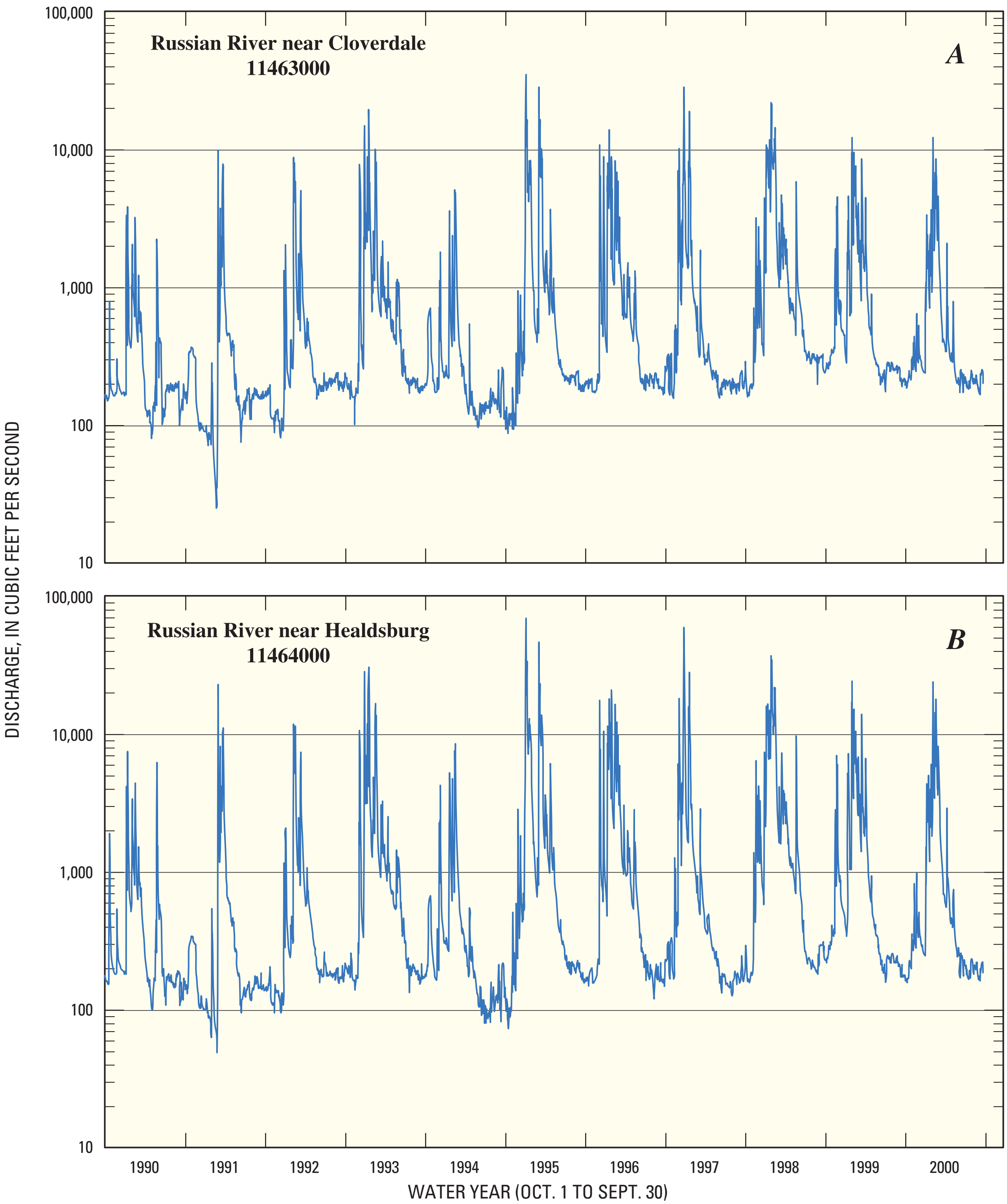
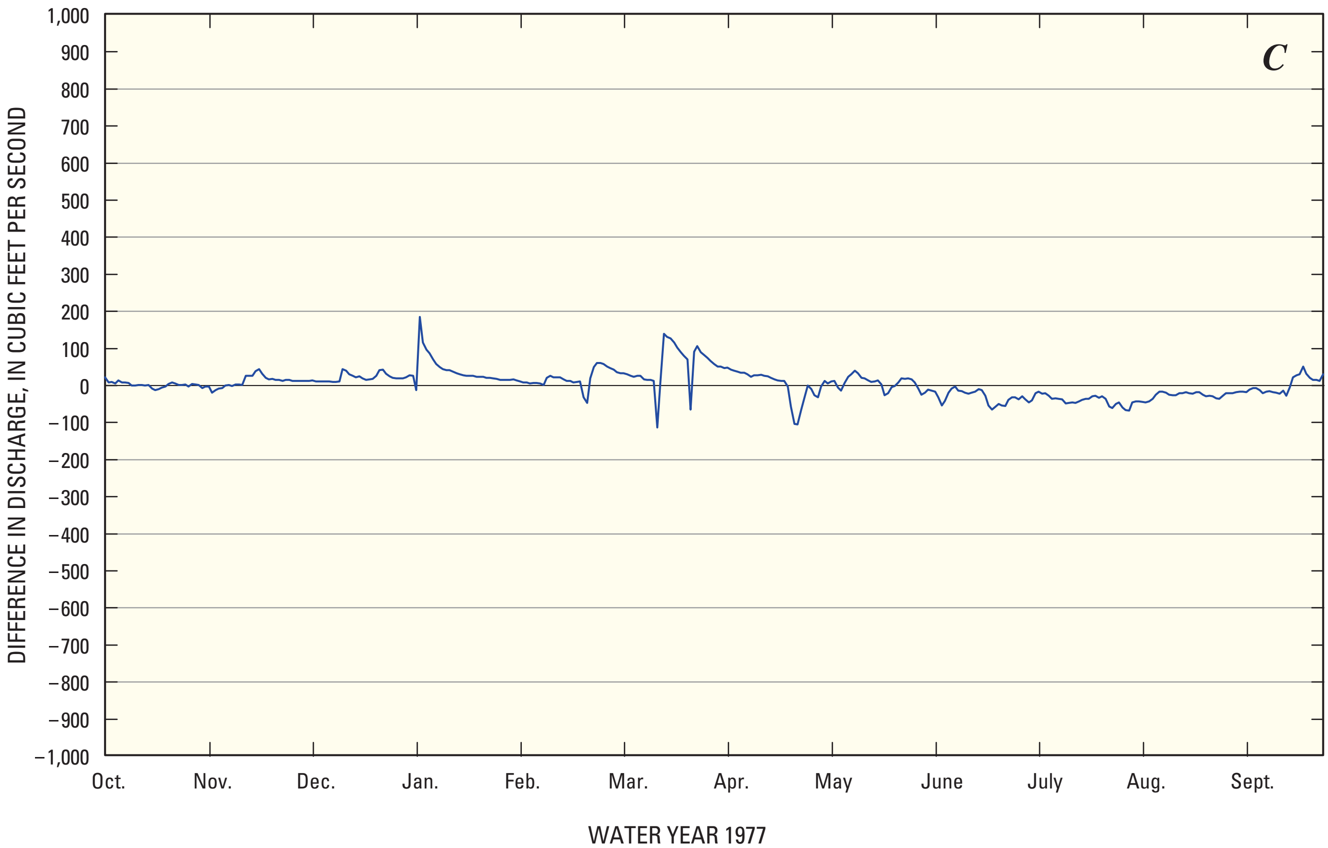


Figure 8. Discharge of Russian River, Sonoma County, California. *A*, Mean daily discharge for water years 1990–2000 near Cloverdale. *B*, Mean daily discharge for water years 1990–2000 near Healdsburg. *C*, Difference in discharge in the Russian River between Cloverdale and Healdsburg for water year 1977. *D*, Difference in discharge in the Russian River between Cloverdale and Healdsburg for water year 1995. *E*, Difference in discharge in the Russian River between Cloverdale and Healdsburg for water year 2000.



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Quaternary alluvial units, as discussed in this report, include alluvial fans, stream terraces, flood-plain deposits, and channel alluvium. All these deposits contain variable amounts of poorly consolidated, uncemented to weakly cemented sand, gravel, cobbles, and boulders, in a matrix of silt- and clay-sized material. The alluvial units have high porosity and, where they consist mostly of coarse-grained material, have high permeability. Where the units contain large fractions of silt and clay, permeability is greatly reduced. Cardwell (1965) estimated that the specific yield of the alluvial units averages about 20 percent in the depth range between 10 and 50 ft below land surface (bls).

Most wells with a high yield are completed in alluvial units that have a saturated thickness that exceeds 50 ft. The high–yielding wells generally are located near the Russian River, which flows along the axis of the valley. Wells that are completed in alluvial units range in yield from a few gallons per minute (gal/min) to more than 1,000 gal/min. Well yields generally increase as saturated thickness, grain size, and sorting increase. Yields of 1,000 gal/min tend to occur in wells that tap alluvial units that are predominantly composed of cobbles, gravel, and sand (Cardwell, 1965).

The Glen Ellen Formation mostly consists of consolidated, weakly- to moderately-cemented silt, and clay with minor sand beds. The large amount of clay-sized material in this formation, although high in porosity, greatly limits permeability. The estimated specific yield of the Glen Ellen in Sonoma Valley (*fig. 1*) is 3 to 7 percent (California Department of Water Resources, 1982); a similar range is likely for Alexander Valley. Well yields from the Glen Ellen generally are lower than those from the alluvial units. However, some wells that tap a few hundred ft of the formation intersect enough thin beds of coarse-grained materials to provide up to 400 gal/min (Cardwell, 1965). The Glen Ellen Formation is an important source of water to wells in the southern part of the study area because its thickness exceeds 400 ft and the overlying alluvial units are thin.

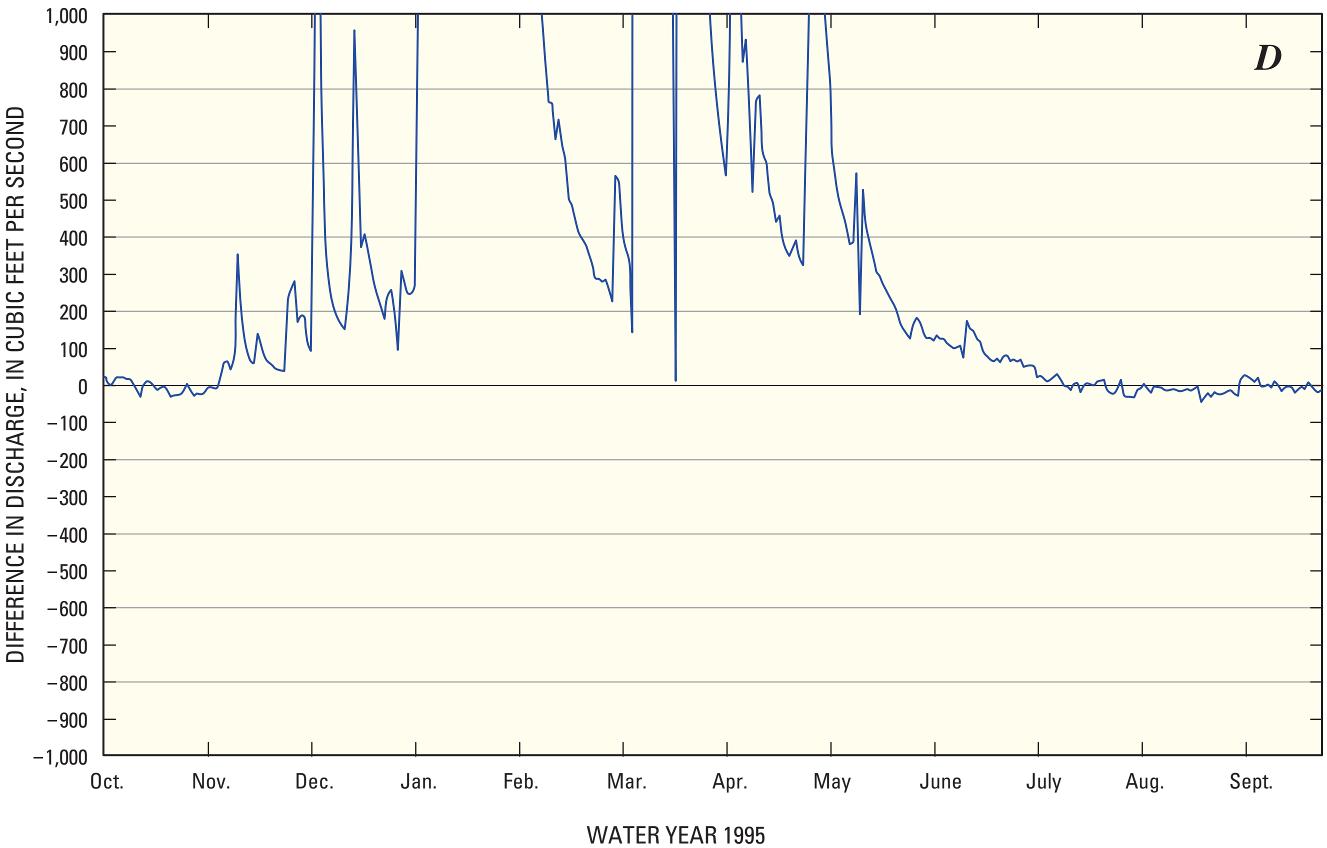


Figure 8.—Continued.

The Sonoma Volcanics have the greatest variability in lithology, and also in water-bearing properties. Within the Sonoma Volcanics, fractured lavas, interflow zones, scoria, and unwelded tuffs provide the best aquifers. Exposures of the Sonoma Volcanics in the study area are limited to andesite and basalt lavas; however, other lithologies may be present in the subsurface. The primary permeability of the lavas is insignificant, except where they are strongly jointed owing to the cooling fractures. The secondary permeability of the lavas is mostly due to fracturing related to folding or faulting, and this can result in rocks with high permeability. Separations between cooling units are commonly seen in outcrops in the study area, and although thin (less than 1 ft), they can be laterally extensive and provide significant transmissivity to the entire lava flow. The interflow zones between lavas often consist of rubbly material and scoria that can have very high porosity and permeability. Unwelded tuffs are composed of ash, lapilli, and larger sized pumice fragments and other lithic clasts. Such units have hydraulic characteristics similar to those of alluvial materials with high porosity and high permeability. The debris-flow deposits and lahars are poorly sorted and contain large fractions of fine-grained materials which, although high in porosity, are low in permeability. An accurate distribution of lithologies within the Sonoma Volcanics at depth throughout the study area is not known, which precludes predicting well productivity. In Sonoma Valley, the combined lithologies of the Sonoma Volcanics have a variable specific yield ranging between 0 and 15 percent (California Department of Water Resources, 1982). A similar range probably applies to Alexander Valley.

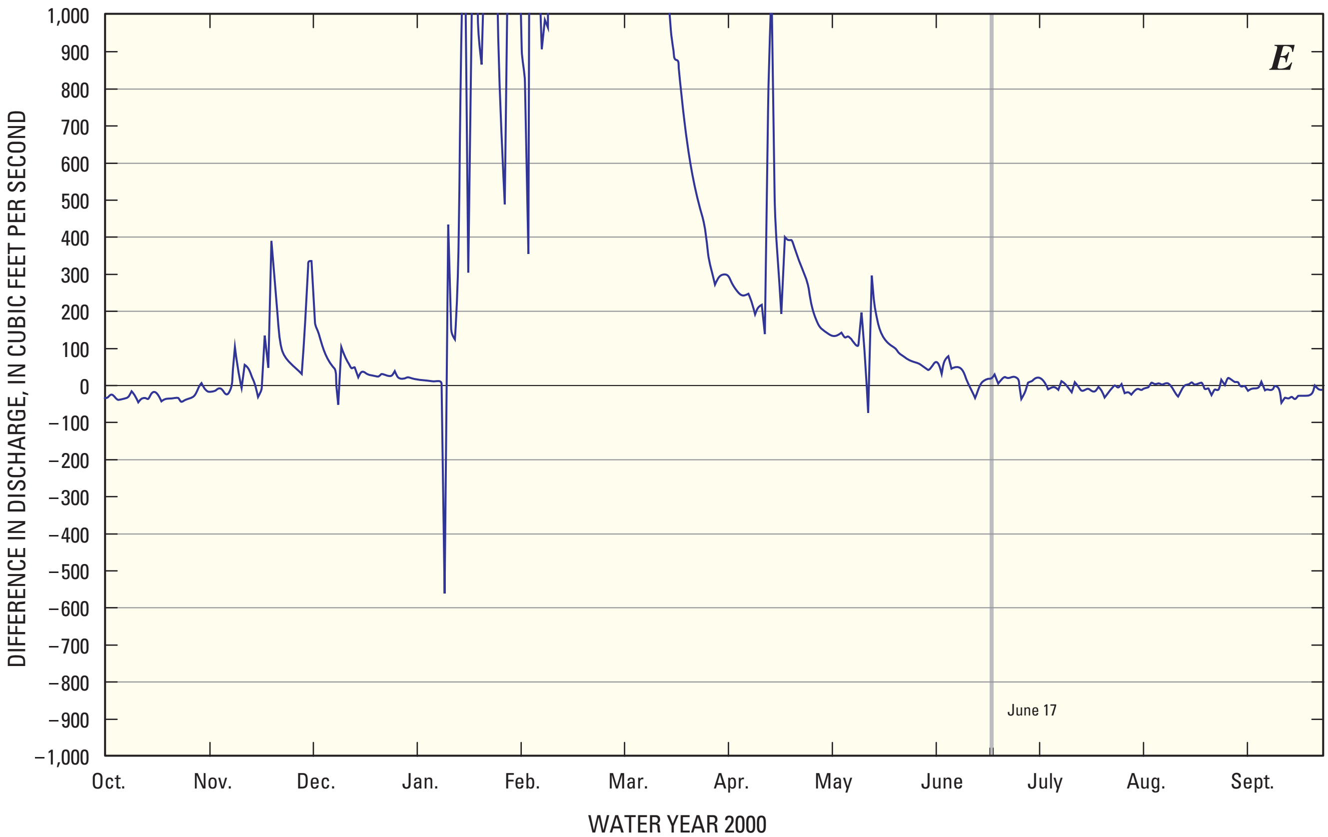


Figure 8.—Continued.

The basement rocks, which include the Great Valley Sequence, the Coast Range Ophiolite, and the Franciscan Complex, generally are considered non-water-bearing because, compared with the overlying formations, these rocks yield much less water to wells. However, in many locations the basement rocks can provide 1 to 5 gal/min of water to wells, which may be enough for an individual domestic supply (California Department of Water Resources, 1958). The basement rocks consist of several different lithologies that have different hydraulic properties. Many wells drilled in the basement rocks result in dry holes. The most indurated lithologies have very low primary porosity and permeability, but where fractured can have significant secondary permeability. The mélange of the Franciscan Complex consists of a fine-grained matrix with embedded clasts and large rock bodies. The fine-grained matrix has high porosity but very low permeability. Wells completed in the mélange typically yield less than 1 gal/min to a few gal/min (California Department of Water Resources, 1982).

Within the study area, ground water occurs under both confined and unconfined conditions. Generally unconfined conditions prevail at shallow depths (less than 200 ft); however, where wells are drilled through thick sections of impermeable rocks (for example, clay or unfractured lavas), confined or semi-confined conditions can exist. Ground water in the alluvial units generally is unconfined because the alluvial units consist of primarily coarse-grained material and generally are less than 100 ft thick. Ground water can occur under confined conditions in the Glen Ellen, the Sonoma Volcanics, and the basement rocks because all these units contain some fine-grained materials and all extend to depths of a few hundred feet or more in places.

The quantity of ground-water storage has been estimated during previous studies. Cardwell (1965) estimated that about 65,000 acre-ft of ground water is stored in the alluvial units, which range between 10 and 50 ft in thickness beneath an area of about 10,500 acres of the valley floor. The California Department of Water Resources (1983) estimated that there is about 602,000 acre-ft of ground-water storage throughout the entire thickness of the basin-fill deposits. This estimate is based on ground-water levels in 1980. However, the total amount of ground water in storage in the watershed has little value in determining the amount of ground water that might be available or the rates at which it can be withdrawn on a sustained basis (Bredehoeft and others, 1982). The amount by which annual ground-water recharge can be increased or discharge decreased generally are more important factors in determining the long-term sustainable yield from a basin.

Water Budget

The study area receives abundant precipitation in most years. The mean annual precipitation for water years 1952 through 2004 is estimated to be about 298,000 acre-ft/yr based on PRISM (Daly and others, 1994; Oregon State University Spatial Climate Analysis Service, accessed January 13, 2006). Part of this amount is absorbed by soils in the study area; the amount absorbed varies from season to season and interannually depending on climatic variables and antecedent conditions in the watershed. The mean annual amount of precipitation absorbed by soils is the soil-moisture deficit replenishment, which is estimated to be about 75,000 acre-ft/yr (equivalent to 11 in. over the study area). This estimate was based on the quantity of precipitation received before stream discharge increased significantly. The soil-moisture deficit is caused by evapotranspiration during the dry months (generally May–September). Evapotranspiration includes the transfer of water from surface-water bodies, soils, and vegetation to the atmosphere. Total annual evapotranspiration is greater than the soil-moisture deficit because plants continue to transpire water and water evaporates from water surfaces even during the cooler months of October to April. The mean annual potential evapotranspiration (Et_o) at Healdsburg between 1986 and 1994, calculated from hourly meteorological measurements, was 50.5 in. (California Department of Water Resources, accessed March 21, 2005). Actual evapotranspiration (Et_a) is much less than Et_o because most of the time soil moisture is below field capacity and many plants have periods of dormancy during part of the year, during which water consumption is greatly reduced. For this study, Et_a was estimated by comparing the soil moisture deficit (SMD) with the calculated Et_o for the months May through September. The ratio of SMD to Et_o for those months is 0.33. Et_a for the entire year was estimated to be 16.7 in. by multiplying annual Et_o (50.5 in.) by 0.33. This estimate is similar to estimates of Et_a reported by the California Department of Water Resources (1980) for various crops. The estimate of Et_a for orchards was about 19.7 inches per year (in/yr). Most of the study area is covered by native vegetation, which, with the exception of riparian vegetation, consumes less water than crops. So the mean Et_a for the study area is probably less than 19.7 in. Total annual Et_a for the study area can be calculated assuming an areally constant Et_a. For the 81,280-acre study area, with an Et_a ranging between 16.7 and 19.7 in., total Et is calculated to range between 113,000 and 133,000 acre-feet per year (acre-ft/yr).

Part of the precipitation falling within the study area finds its way to streams and ultimately leaves the watershed as runoff by way of the Russian River. The mean annual amount of runoff generated within the study area is about 160,000 acre-ft/yr (equivalent to 23.6 in.); this estimate was made using records of discharge for 1952–2004 for the gages near Cloverdale and Healdsburg and using the size of drainage areas within the study area (127 mi^2) compared with the size of the drainage area of the Healdsburg gage (290 mi^2). This estimate is consistent with the estimated mean annual unit-runoff of 21.4 in. for the Russian River drainage between the Cloverdale and Healdsburg gages (stations 11463000 and 11464000) for 1931–63 based on data given by Rantz and Thompson (1967). When the sum of evapotranspiration (using a range of 113,000 to 133,000 acre-ft/yr) and runoff (160,000 acre-ft/yr) is subtracted from the total amount of precipitation (298,000 are-ft/yr) received in the study area, the remainder is the potential amount of ground-water recharge (water that infiltrates to the water table), which is estimated to be about 5 to 25,000 acre-ft/yr. There is considerable uncertainty associated with this estimate because it was computed as residual from other, much larger water-budget components that have considerable uncertainties.

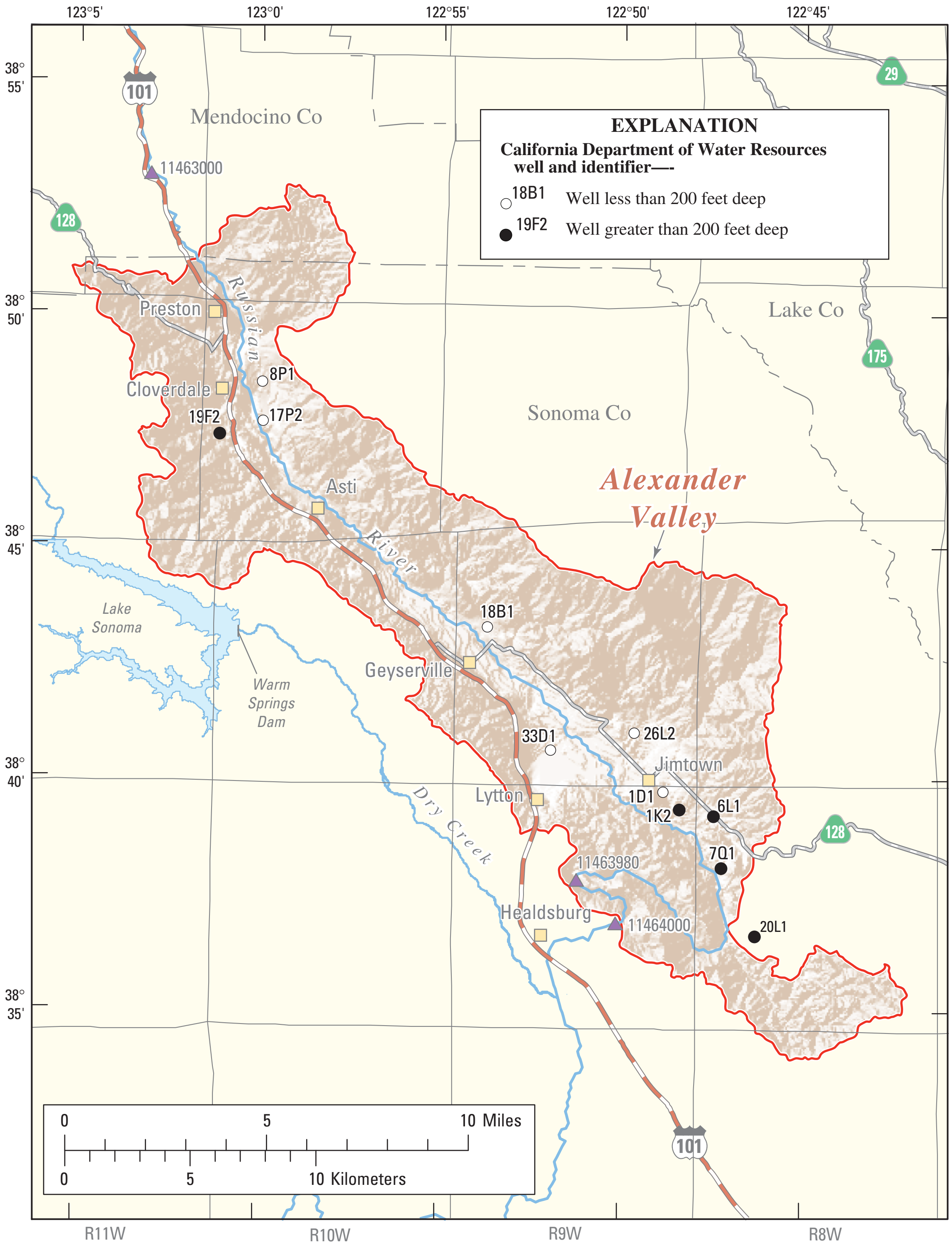
Ground water includes all subsurface water below the water table but does not include moisture held in soils. Ground water is discharged from the watershed directly by springs and seepage into streams. Baseflow in streams is sustained by ground-water discharge. Ground water is used by riparian vegetation that has roots extending below the water table. Plants growing outside the riparian zones can have roots that extend deep enough to extract ground water (Lewis and Burgy, 1964). Ground water can be evaporated directly to the atmosphere in locations where the water table is at, or very near, land surface. Ground water is also pumped from wells to provide supplies for irrigation, municipal, industrial, and domestic uses.

Ground-Water Levels and Movement

Ground-water levels have been measured by California Department of Water Resources in a network of wells on the floor of Alexander Valley (*fig. 9*). Most of the network was developed between the mid-1960s and 1981. Measurements at some wells were discontinued because of difficult access, well-bore obstructions, or other reasons. Other wells were added either to replace wells removed from the network or to improve areal coverage of the initial network. However, the network is still sparse with only three wells in the northern part of the valley, two wells near the middle of the valley, and six wells in the southern part of the valley. Measurements generally were made at these wells in April and October, the beginning and ending of the dry season, respectively.

Despite the effort to avoid making water-level measurements while wells were pumping or recovering from recent pumping, some measurements may have been made during non-static conditions. Measurements suspected of having been affected by recent or nearby pumping were excluded from the analysis of water-level conditions in this report.

In addition to the water levels monitored as part of the DWR network, some earlier water-level measurements were made in a smaller number of wells (Cardwell, 1965).



Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402
Shaded relief base from 1:250,000 scale Digital Elevation Model: sun illumination from northwest at 30 degrees above horizon

Figure 9. Locations of wells in the California Department of Water Resources ground-water-level monitoring network in Alexander Valley, Sonoma County, California.

Ground-water-level measurements do not necessarily represent the water table because hydraulic head can vary with depth in an aquifer. Therefore, the water levels in wells open to a large span of depth intervals represent composite heads for the respective depth intervals. The correct interpretation of ground-water-level data is, in part, dependent on complete well-construction information, including total depth, perforation intervals, seals, and gravel-pack depth. Complete construction information, however, was not available for several of the wells in the water-level monitoring network, which limited analysis and interpretation of the data.

The map of hydraulic head previously published by California Department of Water Resources (1983) is reproduced in this report (*fig. 10A*) to show the general distribution of heads beneath the valley floor. The map shows hydraulic gradients from which the approximate directions of ground-water movement can be determined and changes in hydraulic heads between autumn 1980 and more recent periods can be compared. The general direction of ground-water movement is from recharge areas in the mountains around the perimeter of the study area toward the valley axis and from the northwest end of the valley southeastward toward the narrows east of Healdsburg. The ground-water-level gradient has a strong component transverse to the valley axis in the area east of Lytton where a large number of wells have been drilled (*fig. 11*).

Ground-water-level altitudes for autumn 2002 are shown in *figure 10B*. Data from 2002 were chosen for comparison because water levels had been measured at about the same time of the year as levels measured in 1980, making comparisons of change simpler. The contour lines are based on only eight measurements and therefore are considered approximations of the true water-level altitude. The individual contour lines for the 2002 data were constructed using the 1980 contour lines as a guide of their general configuration and adjusted in accordance with the change in water-level altitude between 1980 and 2002. In general, the changes in water levels between 1980 and 2002 were less than 10 ft. The largest differences were in the area from Geyserville to Jimtown where water levels declined by as much as 26 ft between autumn 1980 and autumn 2002.

Long-Term Changes in Ground-Water Levels

Graphs showing long-term changes in ground-water levels were made using data for wells in the CADWR monitoring network (*fig. 12A–D*). The graphs show data for groups of wells, based primarily on geographic location, to allow comparison of water-level changes in various parts of the study area. Table 4 provides selected well-construction information for these monitoring wells and changes in ground-water levels.

Water-level monitoring has been done at three wells near Cloverdale (*fig. 12A*); however, monitoring at one well tapping alluvium was discontinued in 1999. Data for 1966–2004 are available for the other two wells One of the active wells (11N/10W-8P1) is 28 ft deep and completed in alluvium; water levels declined about 5 ft at this well between spring 1967 and spring 2004. The other active monitoring well (11N/10W-19F2) is 334 ft deep and completed in the Franciscan Complex; the difference in water levels in this well was less than 1 ft between spring 1967 and spring 2004 (*fig. 12A*, *table 4*). Between 1996 and 2004, seasonal water-level differences were mostly less than 1 ft, and smaller than earlier years. This smaller difference may be caused by a shift in the timing of measurements from March or April to May or June, and from October to November or December.

Two wells in the network are within about 1 mi of Geyserville (*fig. 10B*). One well (10N/9W-33D1) is 98 ft deep and completed in the Glen Ellen Formation, and the other well (10N/9W-18B1) is 178 ft deep and completed in the Sonoma Volcanics (*table 4*). Both wells show water-level declines of about 4 ft (comparing measurements made in spring of each year) over periods of 23 to 37 years (*fig. 12B*). For well 33D1, the annual low (autumn) water levels have shown slightly greater declines, probably caused by increased pumping locally.

Four wells in the network are located near Jimtown (*fig. 10B*). Three of the wells (9N/9W-1D1, 9N/9W-1K2, and 9N/8W-6L1) are completed in the Glen Ellen Formation and one well (10N/9W-26L2) is completed in alluvium. The periods of record for these wells range between 23 and 37 years. Over the period of record, all four wells have had water-level declines of 1 to 8 ft (*fig. 12C*, *table 4*). Water levels in well -1D1 have shown increased seasonal variation since about 2000. The recent amplitude of water level variation (difference between spring and autumn water levels) at this well exceeds 30 ft. This is probably caused by increased local pumping.

Two wells in the network (9N/8W-7Q1 and 9N/8W-20L1) are in the southern area (*fig. 10B*). Both are drilled into the Glen Ellen Formation, however, well -7Q1 also taps alluvium (*table 4*). Well -7Q1 is 490 ft deep and had a 2-ft rise in water level between 1974 and 2004. Note that water levels at well -7Q1 declined significantly through the early 1980s (fig. 12*D*). This well has not been used for supply since some time between April and October 1985. The lack of pumping at this well is clearly reflected by the smaller annual water-level fluctuations that begin in 1985 (*fig. 12D*), which could explain the modest rise in water levels since 1985. Well -20L1 is 204 ft deep and had a 41-ft decline between spring 1974 and spring 2003; most of this change has occurred since 2000. This decline in water level probably is due to the pumping of larger quantities of ground water in recent years.

Table 4. Well construction information and water-level change in wells in the California Department of Water Resources ground-water level monitoring network in Alexander Valley, Sonoma County, California.

[See figure 5 for explanation of geologic units. Depths in feet (ft) below land-surface datum; —, missing data]

State well No.	Area	Well depth	Depth of perforated interval	Geologic unit	Period of record[1]	Number of years[2]	Water-level change (ft)		
							Period of record	Fall 1980– Fall 2002	Spring 1981– Spring 2003
11N/10W-8P1	Cloverdale	28	8–28	Qal	1967–2004	37	–5	–4	–3
11N/10W-17P2		32	28–32	Qal	1967–1999	32	–5	—	—
11N/10W-19F2		334	90–320	KJf	1967–2004	37	0	+6	0
10N/9W-18B1	Geyserville	178	—	Tsv	1967–2004	37	–4	–4	–2
10N/9W-33D1		98	83–98	QTge	1981–2004	23	–4	–9	–5
10N/9W-26L2	Jimtown	40	—	Qal	1967–2004	37	–7	–8	–4
9N/9W-1D1		108	[3]88–108	QTge	1981–2004	23	–1	–26	–2
9N/9W-1K2		403	[3]50–264	QTge	1981–2004	23	–6	—	–6
9N/8W-6L1		240	160–240	QTge	1981–2004	23	–8	+8	–8
9N/8W-7Q1	Southern	490	—	Qal+QTge	1973–2004	31	+2	—	+6
9N/8W-20L1		204	130–204	QTge	1974–2003	29	–41	—	–40

[1]Period of record between first and last spring measurement.

[2]Number of years between the first and last spring measurements.

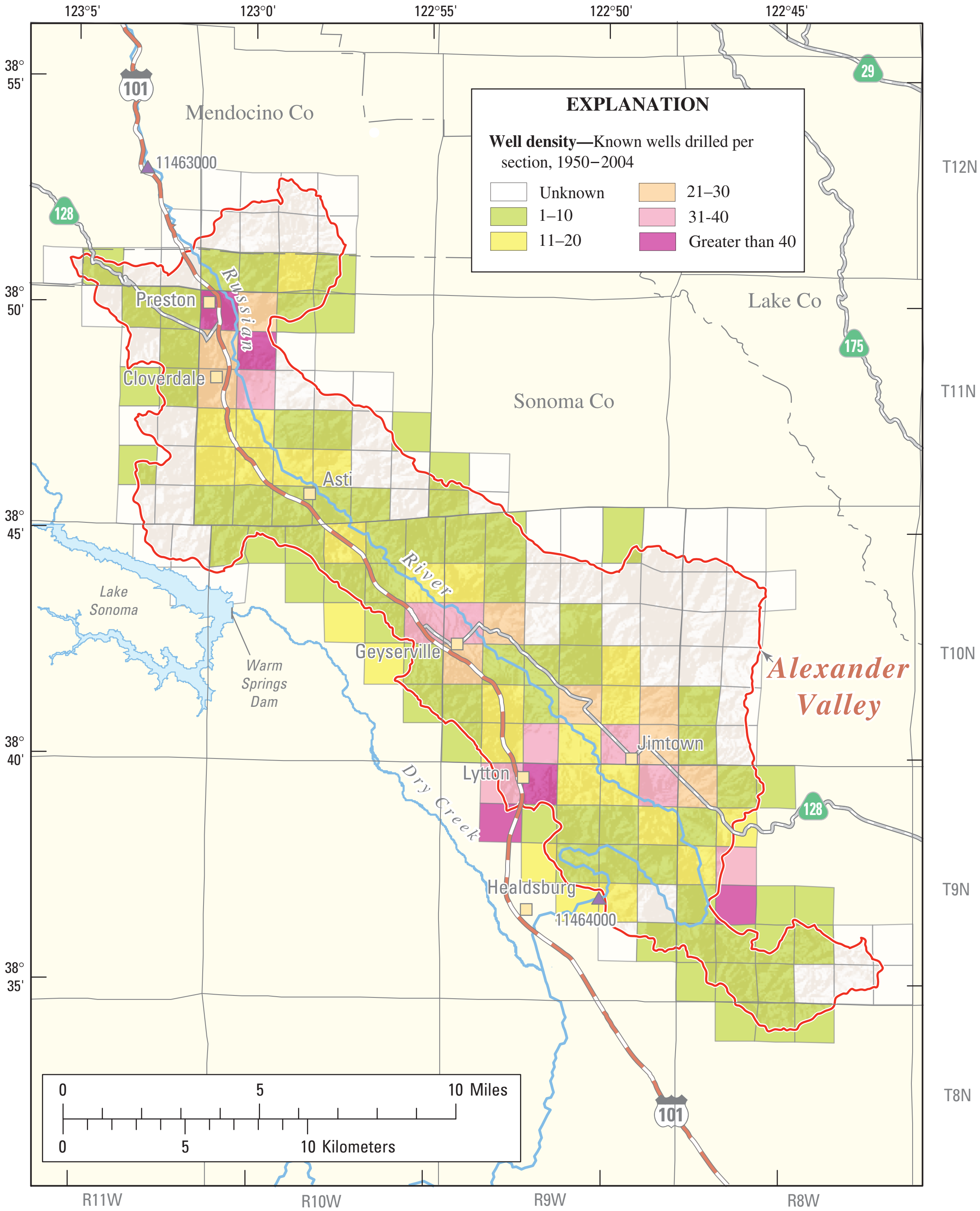
[3]Depth information uncertain.

Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402
Shaded relief base from 1:250,000 scale Digital Elevation Model: sun illumination from northwest at 30 degrees above horizon

Figure 10. Generalized hydraulic head in Alexander Valley, Sonoma County, California. *A*, Autumn 1980. *B*, Autumn 2002.

Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402
Shaded relief base from 1:250,000 scale Digital Elevation Model: sun illumination from northwest at 30 degrees above horizon

Figure 10.—Continued.



Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402
Shaded relief base from 1:250,000 scale Digital Elevation Model: sun illumination from northwest at 30 degrees above horizon

Figure 11. Drilled wells per section in Alexander Valley, Sonoma County, California, 1950–2004.

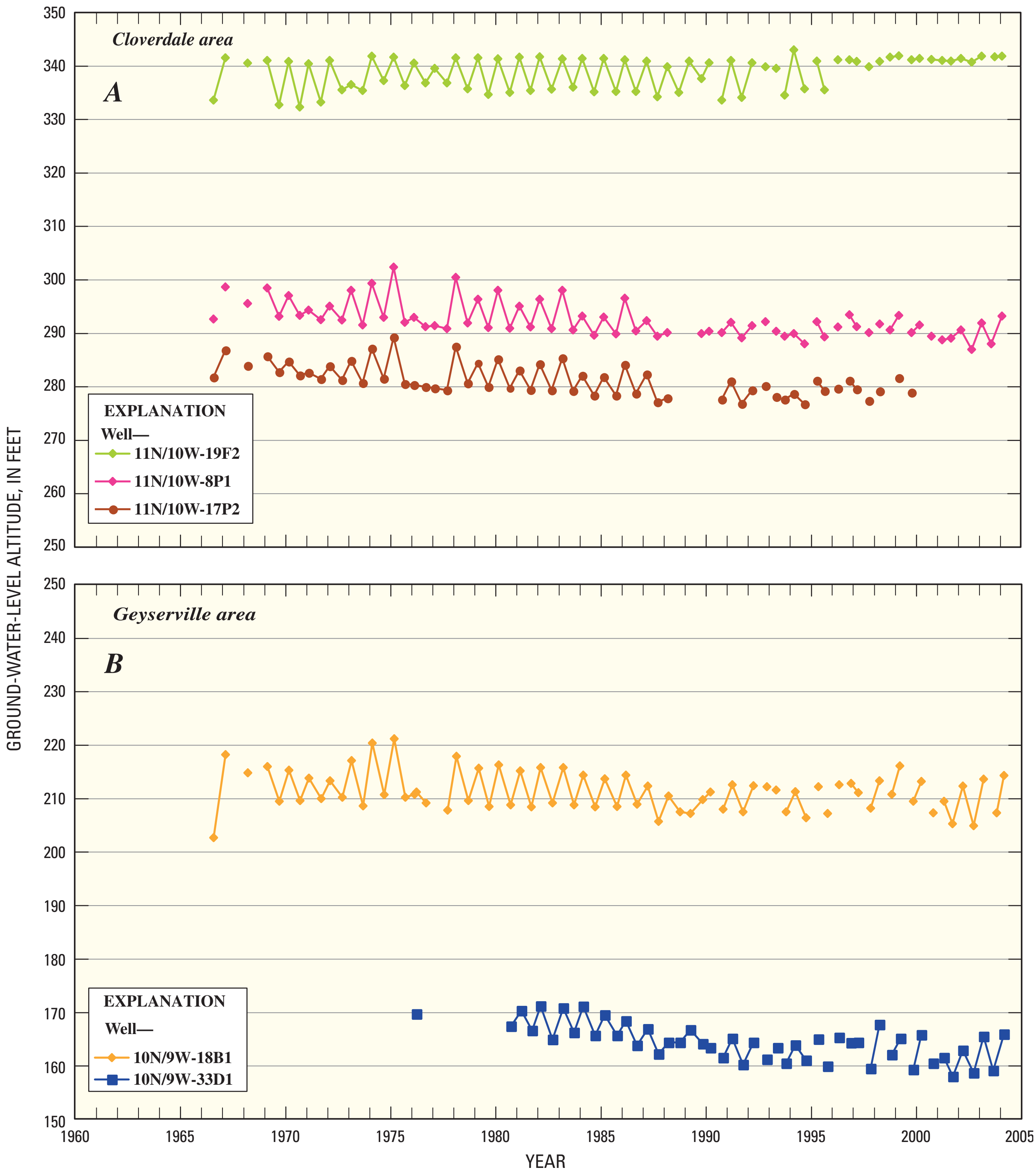


Figure 12. Water level hydrographs for selected wells in Alexander Valley, Sonoma, County, California. *A*, Cloverdale area. *B*, Geyserville area. *C*, Jimtown area. *D*, southern area. Data points are connected by lines only for consecutive seasonal high or low water levels or where the data are less than six months apart. Datum is NGVD29.

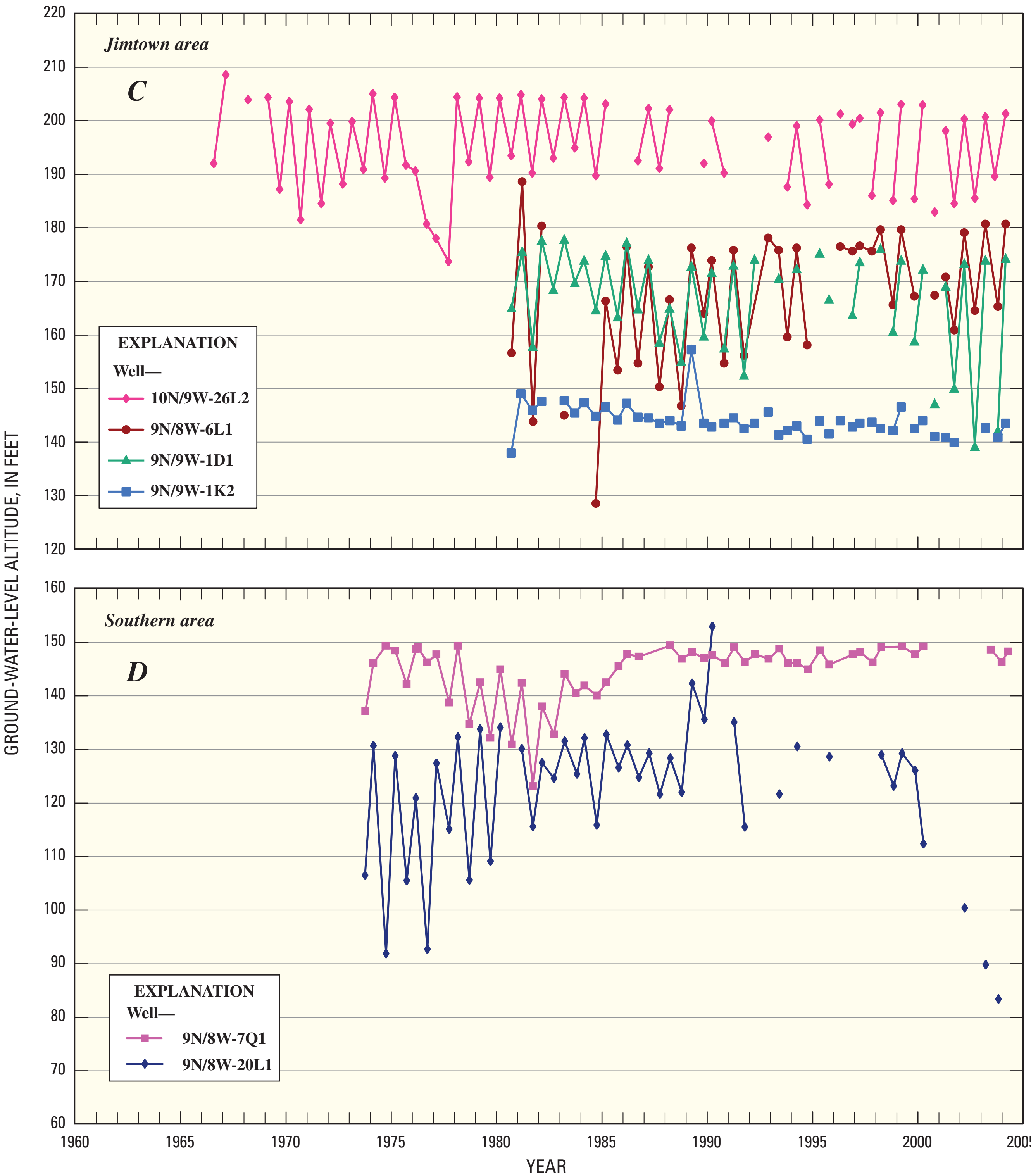


Figure 12.—Continued..

In summary, 9 of the 11 monitoring wells in the network had slight water-level declines over their varying periods of record (*table 4*). Comparing water-level changes for these wells for the same time period provided a consistent basis to compare water-level changes in different parts of the study area. First, water levels were compared for the period between spring 1981 and spring 2003. This allowed an assessment of the balance between ground-water use in the previous irrigation season and ground-water recharge during the rainfall season. Eight of 10 wells had ground-water-level declines between spring 1981 and spring 2003, one well had a 6-ft rise (9N/8W-7Q1), and one well had no change (11N/10W-19F2). The declines were 8 ft or less for all but one well (9N/8W-20L1), in the southern part of the area, which had a 41 ft water-level decline. The geneal condition of slightly lower ground-water levels at the end of the rainfall season in recent years suggests a small imbalance in which ground-water use slightly exceeds annual recharge. Water levels also were compared for the period between autumn 1980 and autumn 2002. Ground-water levels generally were lower in 2002 (by 4 to 26 ft) in the Jimtown and Geyserville areas at the end of the irrigation season. However, the water level in one well near Jimtown (9N/8W-6L1) was higher by 8 ft in 2002 (*table 4*). Data were too sparse to make a determination of water-level changes in other parts of the valley.

Ground-Water and Surface-Water Quality

Water-chemistry data compiled by the USGS and California Department of Water Resources were used to help characterize the spatial variations in surface- and ground-water quality, and to help identify the source and movement of ground water in the Alexander Valley. Ground-water and surface-water data from sites located in and adjacent to the Alexander Valley were used for this study (*fig. 13*; *table 5* and *Appendix A*). Field constituent data (water temperature, pH, specific conductance, and alkalinity), and major ion, trace element, silica, and nutrient data collected during 2002–2004 from 1 site along the Russian River (Russian River at Digger Bend near Healdsburg, station id 11463980) and from 13 wells are summarized in *Appendix A*. Specific conductance measurements at eight wells sampled from 1969 through 2004 are summarized in *table 6*. Historical water-chemistry data (1951–2001) for 1 additional surface-water site on the Russian River (Russian River near Healdsburg, 11464000) and for 23 wells in the Alexander Valley were compared with recent (2002–04) data. USGS water-chemistry data presented in this report include field measurements from 1 surface-water site monitored as part of a separate USGS study of the lower Russian River (Marisa Cox, U.S. Geological Survey, Menlo Park, written commun., 2005) and data from 5 wells sampled in 2004 for the Ground-water Ambient Monitoring and Assessment program (GAMA), a comprehensive statewide effort designed to understand and identify water-quality risks to ground-water resources (Kulongoski and others, 2006).

In general, water chemistry can vary with depth in ground-water systems. In the study area, ground-water wells have a fairly narrow range of completed depths and perforated intervals. Among 28 wells with historical (1951–2001) and recent (2002–2004) major ion and specific conductance data used for this study, 19 wells (68 percent) are drilled or completed (cased) at a depth of less than 200 ft bls, 6 wells (21 percent) are completed at a depth greater than 200 ft, and the remaining 3 wells have no depth information (*table 5*). For wells with water-chemistry and perforation information, the average perforation depth for each depth category is 57 ft (completed well depth less than 200 ft) and 220 ft (completed well depth greater than 200 ft). Less than half (43 percent) of the wells sampled have available perforation information; thus, to make a statistically meaningful comparison of water chemistry between depths, the wells were divided into the two depth categories indicated for illustration and discussion in this report.

Methods of Water Sampling and Analysis

Surface-water samples for the measurement of selected field constituents including dissolved oxygen, pH, specific conductance, and water temperature were collected using a DH-81 sampler according to methods given in Wilde and others (1999). USGS ground-water samples from wells were collected from faucets either at or near the well head to minimize potential chemical alteration of the water between the well and the sampling point. Prior to the collection of the ground-water samples, the wells were purged a minimum of three casing volumes of water. Sequential measurements of specific conductance, pH, and temperature were made at 5-minute intervals until readings had stabilized to ensure they were representative of the ground water. All USGS samples collected for the analysis of major ions, trace elements, silica, and nutrients were collected, treated, and preserved following procedures outlined by U.S. Geological Survey (1997 to present). These samples were analyzed at the USGS National Water Quality Laboratory at Arvada, Colorado, using standard analytical methods described by Fishman and Friedman (1989), Fishman (1993), and Struzeski and others (1996). All California Department of Water Resources samples were analyzed at the California Department of Water Resources Bryte Analytical Lab in West Sacramento, California (Bruce Agee, California Department of Water Resources, written commun., 2005). CADWR laboratory analyses and field measurements were done according to the referenced methods of the American Public Health Association (1999), and the U.S. Environmental Protection Agency (1993, 1994).

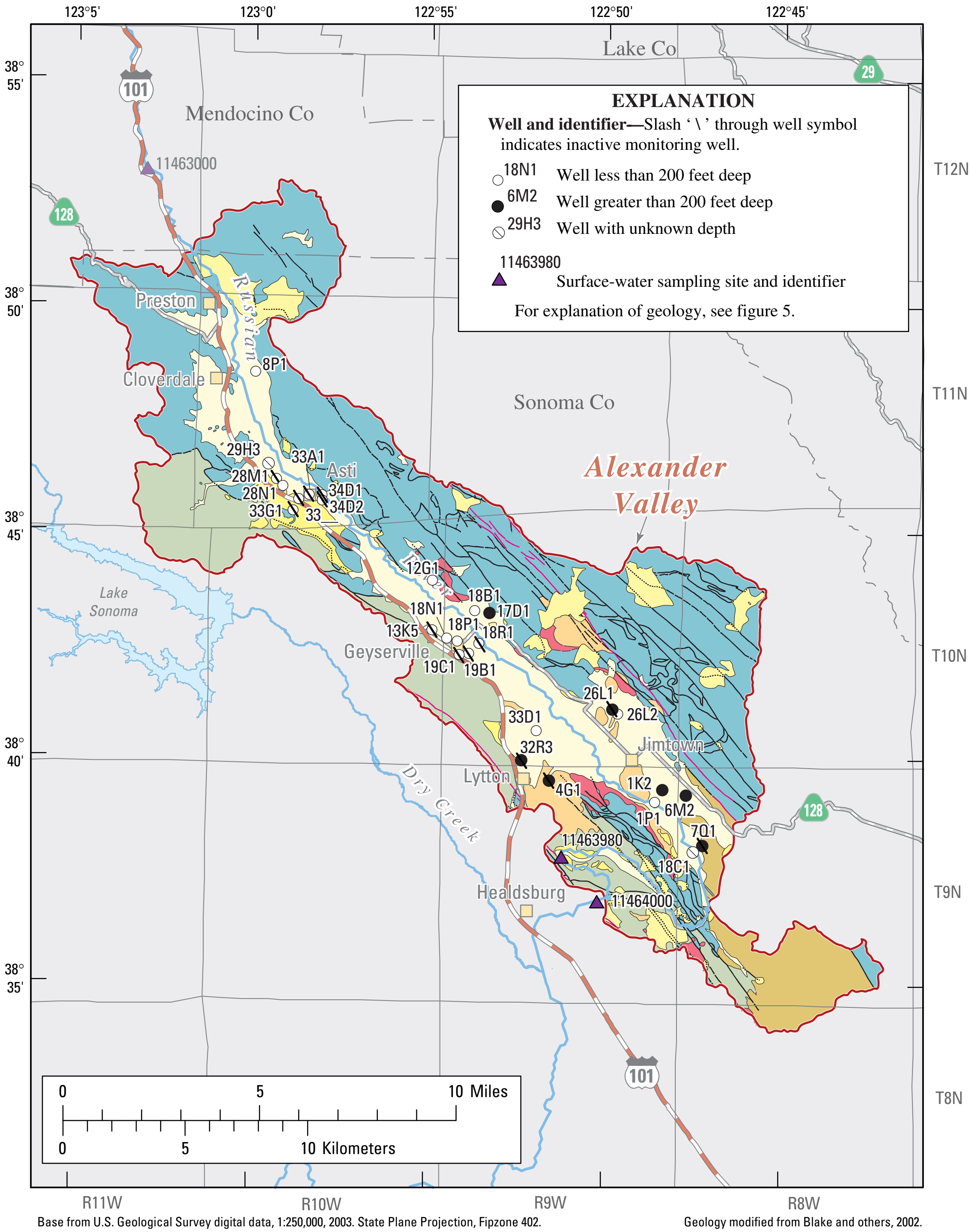


Figure 13. Location of ground- and surface-water quality sampling sites, Alexander Valley, Sonoma County, California.

Table 5. Construction data for selected wells used for water-chemistry sampling in the Alexander Valley, Sonoma County, California.

[State well No.: See well-numbering diagram in text; see figure 13 for site locations; USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database; depths in feet below land surface; land-surface altitude in feet above sea level; —, no data; data sources: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources]

State well No.	USGS site identification No.	Depth drilled	Depth cased	Depth of perforated interval	Land-surface altitude	Period of water-chemistry data used in report	Data source
9N/8W-6M2	383916122473501	600	600	125–600	190	2004	USGS
9N/8W-7Q1	—	490	490	—	160	1957–80	CADWR
9N/8W-18C1	383758122471901	—	—	—	—	2004	USGS
9N/9W-1K1	—	—	—	—	170	1975–2002	CADWR
9N/9W-1P1	—	—	90	—	160	1957–2002	CADWR
9N/9W-4G1	—	320	320	220–320	220	1951–57	CADWR
10N/9W-17D1	384309122531301	315	315	20–315	233	2004	USGS
10N/9W-18B1	384320122534201	180	178	—	230	1972–2002	CADWR
10N/9W-18N1	—	66	66	4–56	215	1976–2003	CADWR
10N/9W-18P1	384238122541201	120	120	62–120	207	2004	USGS
10N/9W-18R1	—	—	[1]14	—	—	1957–64	CADWR
10N/9W-19B1	—	43	—	—	200	1951	CADWR
10N/9W-19C1	—	25	—	—	—	1951	CADWR
10N/9W-26L1	—	[1]320	[1]320	[1]43–244	208	1957–86	CADWR
10N/9W-26L2	—	—	40	—	205	1973–2003	CADWR
10N/9W-32R3	—	245	—	—	175	1952–60	CADWR
10N/9W-33D1	—	[1]98	98	83–98	178	1972–2003	CADWR
10N/10W-12G1	—	33.5	33.5	12–33.5	228	1975–1985	CADWR
10N/10W-13K5	—	172	172	75–172	—	1974	CADWR
11N/10W-8P1	384831122594701	32	32	8–28	305	1972–2003	CADWR
11N/10W-28M1	—	—	21	—	260	1951–52	CADWR
11N/10W-28N1	—	—	19	—	—	1957–2002	CADWR
11N/10W-29H3 [2]	384628122592701	—	—	—	415	2004	USGS
11N/10W-33A1	—	20	—	—	255	1951–63	CADWR
11N/10W-33__ [3]	—	40	30	[1]10–30	—	1956	CADWR
11N/10W-33G1	—	20	18	—	290	1951–64	CADWR
11N/10W-34D1	—	—	5	—	—	1951	CADWR
11N/10W-34D2	—	—	4	—	—	1951	CADWR

[1] Depth information uncertain.

[2] Projected State well number, verification pending.

[3] Location uncertain.

Table 6. Summary of laboratory conductivity measurements for samples from selected ground-water wells, Alexander Valley, Sonoma County, California, 1969–2004.

[Samples were collected and analyzed by the California Department of Water Resources. See figure 13 for locations of wells; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mm/dd/yyyy, month/day/year]

Date (mm/dd/yyyy)	Electrical conductance (µS/cm)	Date (mm/dd/yyyy)	Electrical conductance (µS/cm)	Date (mm/dd/yyyy)	Electrical conductance (µS/cm)
		9N/9W-1K1			
06/12/1975	347	08/17/1984	311	09/18/2002	438
08/03/1977	298	08/28/1986	348		
07/29/1980	300	08/27/1998	374		
		9N/9W-1P1			
07/08/1969	333	08/06/1981	433	09/01/1993	431
07/16/1970	360	08/10/1983	349	08/27/1998	398
07/26/1973	388	08/18/1987	389	09/18/2002	357
06/23/1976	362	08/31/1989	418		
08/09/1978	351	09/19/1991	434		
		10N/9W-18B1			
08/10/1972	306	09/17/1986	322	09/18/2002	400
08/08/1974	288	08/25/1992	410	09/12/2004	372
08/03/1977	431	08/29/1995	365		
07/16/1980	304	08/27/1998	374		
		10N/9W-18N1			
06/23/1976	345	08/18/1987	336	08/24/1999	350
08/09/1978	373	09/10/1990	413	09/17/2001	362
07/09/1981	369	08/25/1992	378	09/24/2003	377
08/10/1983	294	08/29/1995	335		
08/28/1985	359	09/16/1997	354		

Table 6. Summary of laboratory conductivity measurements for samples from selected ground-water wells, Alexander Valley, Sonoma County, California, 1969–2004—Continued.

[Samples were collected and analyzed by the California Department of Water Resources. See figure 13 for locations of wells; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mm/dd/yyyy, month/day/year]

Date (mm/dd/yyyy)	Electrical conductance (µS/cm)	Date (mm/dd/yyyy)	Electrical conductance (µS/cm)	Date (mm/dd/yyyy)	Electrical conductance (µS/cm)
10N/9W-26L2					
07/25/1973	535	08/17/1984	496	08/29/1995	692
06/12/1975	538	08/28/1986	583	09/16/1997	614
08/03/1977	454	08/30/1988	605	08/24/1999	615
07/16/1980	544	09/10/1990	740	09/17/2001	697
09/22/1982	529	08/25/1992	744	09/24/2003	805
10N/9W-33D1					
08/09/1972	288	08/10/1983	325	09/01/1993	373
08/08/1974	304	08/28/1985	349	09/16/1997	457
06/23/1976	310	08/19/1987	442	08/24/1999	392
07/12/1979	324	08/31/1989	342	09/17/2001	441
07/09/1981	325	09/19/1991	384	09/24/2003	438
11N/10W-8P1					
08/09/1972	419	09/22/1982	357	08/25/1992	425
08/08/1974	359	08/17/1984	352	09/16/1997	402
06/23/1976	384	08/28/1986	356	08/24/1999	396
08/09/1978	421	08/30/1988	388	09/17/2001	426
07/16/1980	353	09/10/1990	419	09/24/2003	442
11N/10W-28N1					
09/08/1969	318	07/09/1981	278	09/19/1991	357
07/15/1970	388	09/10/1983	362	09/01/1993	392
08/08/1974	440	08/28/1985	377	08/29/1995	425
06/23/1976	454	08/19/1987	340	08/27/1998	237
07/12/1979	386	08/31/1989	370	09/18/2002	252

Ground-Water and Surface-Water Chemistry

Water-Quality Monitoring

Ground-water quality in the Alexander Valley has been monitored since 1950. Most sampling efforts represented a one-time analysis for short-term studies or individual well-specific assessments. Data shown in this report are available for 28 wells (*fig. 13*, *table 5*), but only 11 wells have sufficient data for determining the recent (2002–04) ionic composition of ground water. A few select wells have been repeatedly sampled every 2 to 3 years for more than 10 years. The longest sustained water-quality monitoring effort in the Alexander Valley has been done by the CADWR. Since the late 1950s, the CADWR has sampled and analyzed ground water for major ions (calcium, magnesium, potassium, sodium, chloride and sulfate), boron, nitrate, total dissolved solids, total alkalinity, electrical conductance, pH, and water temperature. Water-chemistry data covering a minimum of 10 years and maximum of 45 years is available for 13 wells that have been monitored by CADWR, including 8 wells that are currently (2004) monitored. Samples from these wells are collected on average every 2 to 3 years between the months of July and September. Water-quality monitoring of surface water in the Alexander Valley has occurred sporadically since 1951. Eight sites on the Russian River between Cloverdale and Healdsburg have been sampled by the USGS, primarily for nutrients and microbiological constituents. The Russian River near Healdsburg (station id 11464000) is the only surface-water site for which multiple analyses for major ions, trace elements, and nutrients for multiple, consecutive years (1951–66 and 1980) are available.

General Chemical Composition of Ground and Surface Water

Selected samples collected by the USGS from wells and from the Russian River in 2002–04 were measured on site for dissolved oxygen, pH, specific conductance, water temperature, and alkalinity following procedures outlined by the U.S. Geological Survey (1997 to present). Dissolved oxygen concentrations ranged from 0.1 to 11.4 milligrams per liter (mg/L); the highest concentrations were measured in samples from the Russian River at Digger Bend near Healdsburg (*Appendix A*). The maximum concentration of dissolved oxygen in ground water was 5.7 mg/L in a sample from well 10N/9W-18P1, which is perforated from 62 to 120 ft. bls. The pH of all samples collected by both the USGS and the CADWR during 2002–04 ranged between 6.8 and 8.5 (*Appendix A*). Specific electrical conductance (conductivity), a measurement of the ability of water to conduct an electrical charge and an indicator of ionic concentration, ranged from 240 microsiemens per centimeter (µS/cm) (November 2003 sample from Russian River near Healdsburg) to 799 µS/cm (September 2003 sample from well 10N/9W-26L2, which has a depth of 42 ft bls). Although recent seasonal data representing the full range of conductivity values are unavailable, conductivity can be expected to vary depending on the location and the time of year. For example, the highest conductivity values for surface water can be expected to occur in the late summer and autumn months corresponding to the lowest surface-water flows of the season. Conversely, the lowest conductivity values can be expected to occur in the late winter and spring corresponding with the highest surface-water flows. Conductivity and discharge for the Russian River near Healdsburg (11464000) for the period 1951–66 are strongly correlated [conductivity = 603.41 (discharge)-0.1461; R^2= 0.71].

Water-chemistry data for samples collected from 11 wells during 2002–04 indicate that water quality in the study area generally is acceptable for potable use (*Appendix A*). The water from two wells, however, each contained one constituent in excess of the recommended standards for drinking water. Water in a sample from well 9N/8W-6M2 had a concentration of manganese (241 µg/L) that exceeded the secondary drinking-water standard of 50 µg/L (U.S. Environmental Protection Agency, 2002; California Department of Health Services, accessed April 15, 2005). Oxygen and nitrate concentrations in the same sample were reported at detection limits, suggesting that dissolution of manganese could be caused by low oxidation/reduction (redox) conditions. Boron, a constituent of particular concern because of its potential effects on crops, exceeded the 1,000 µg/L California Department of Health Services notification level in a sample from well 11N/10W-29H3 (1,350 µg/L).

The ionic composition of historical surface- and ground-water samples (1951–2001) and of recent ground-water samples (2002–04) are plotted on trilinear diagrams (*figs. 14* and *15*, respectively). A trilinear diagram shows the proportions of common cations and anions for comparison and classification of water samples independent of total analyte concentrations (Hem, 1985). Trilinear diagrams can be used to identify groups of samples that have similar relative ionic concentrations (Freeze and Cherry, 1979). Historical surface-water data plotted on *figure 14A* include 32 samples with complete major-ion analyses collected by the USGS between 1951 and 1966 from one surface-water site on the Russian River (station id 11464000). Although these samples represent spring and late summer conditions for 15 consecutive years, it is uncertain if they are representative of surface-water quality throughout the Alexander Valley because of the lack of comparable data from other locations. Historical ground-water data plotted on *figure 14* are for 96 samples collected by California Department of Water Resources from 23 wells. Recent data, plotted on *figure 15*, are for 11 samples (5 collected by the USGS and 6 collected by the California Department of Water Resources) from 11 wells. Well 10N/9W-18B1, which was sampled twice during 2002–04, is represented in *figure 15* by the latest (2004) analyses listed in *Appendix A*.

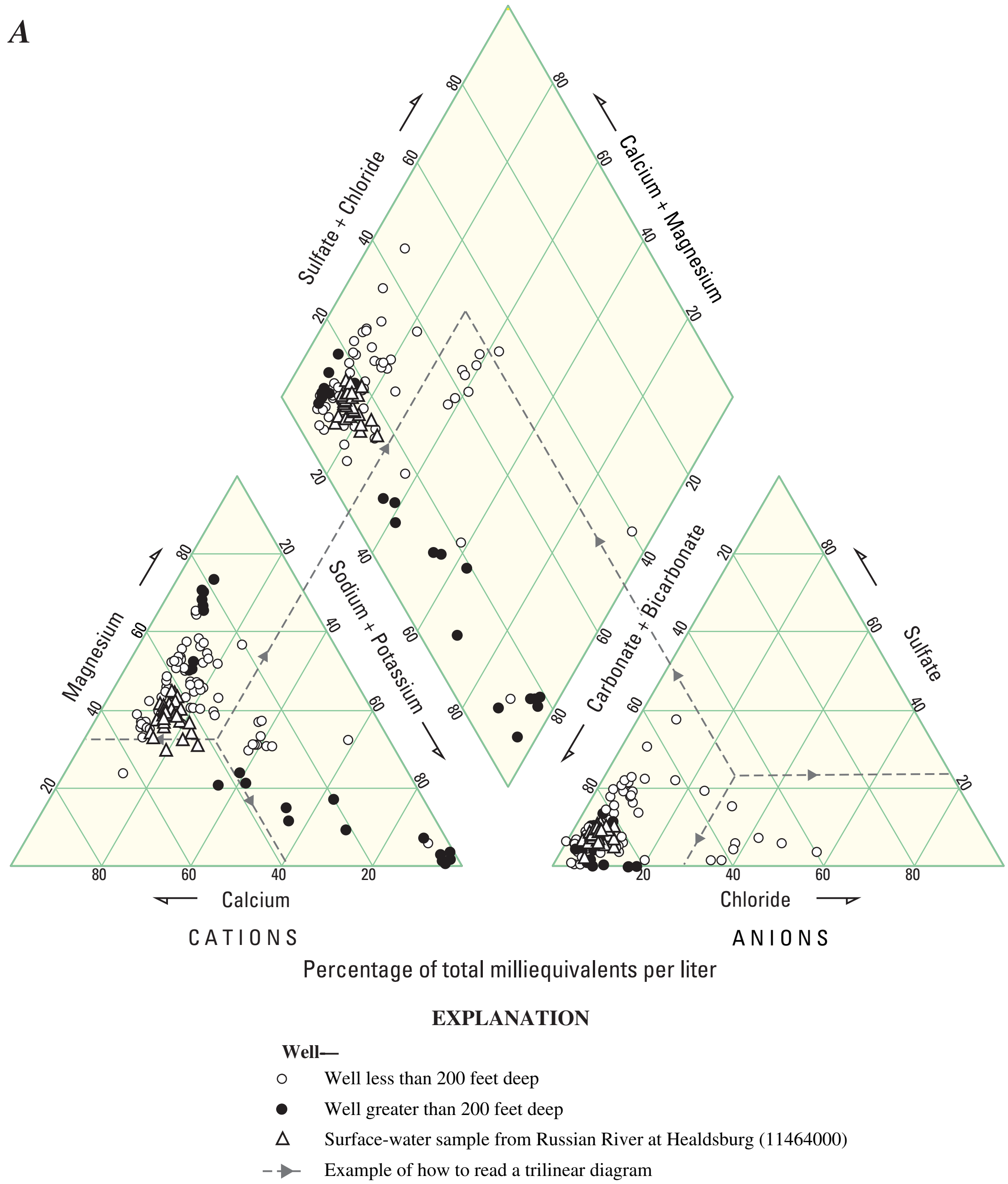


Figure 14. Chemical composition of water from selected ground- and surface-water sampling sites in the Alexander Valley, Sonoma County, California, 1951–2001. *A*, All sites. *B*, Wells in sections 9N/8W and 9N/9W. *C*, Wells in section 10N/9W. *D*, Wells in sections 10N/10W and 11N/10W.

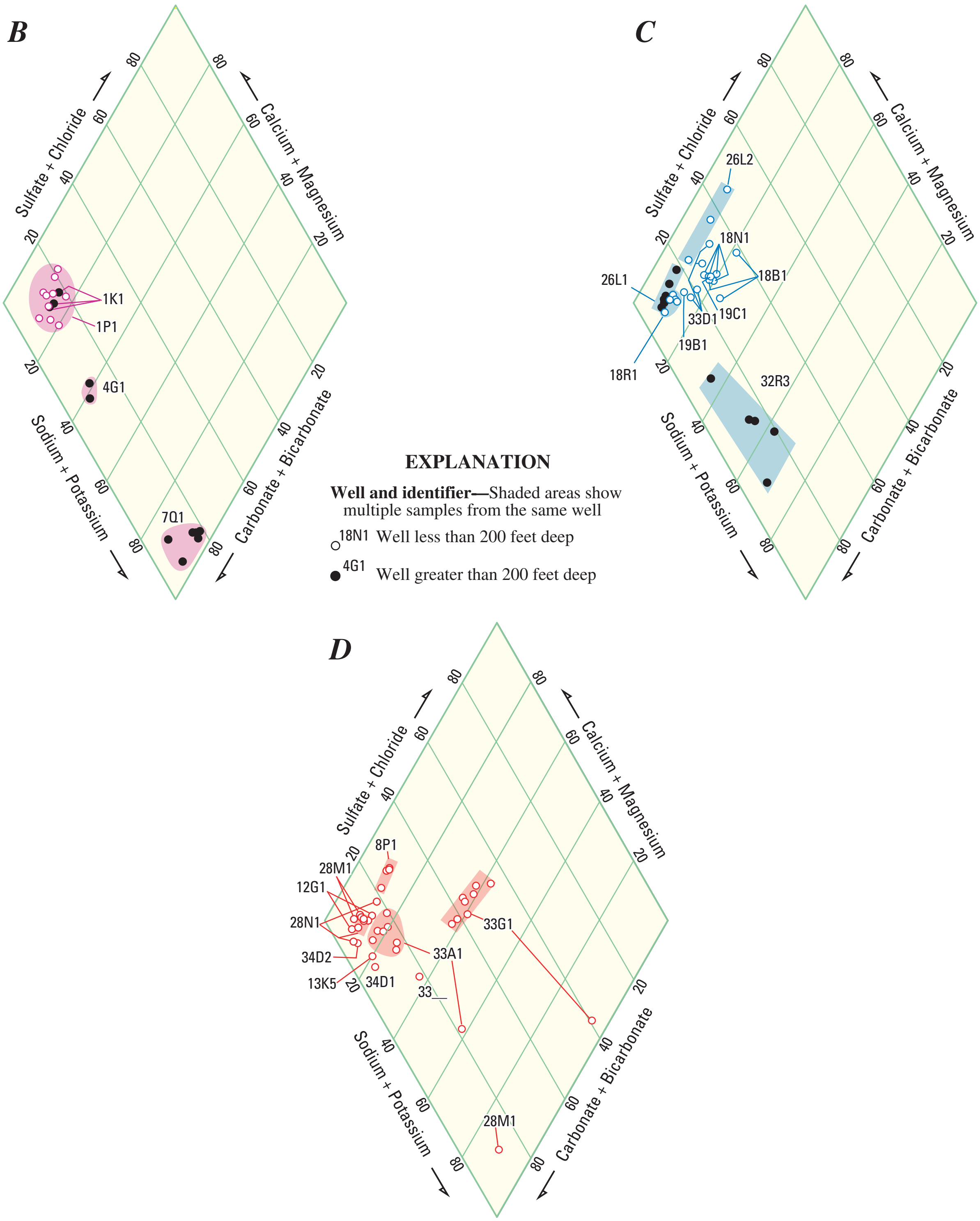
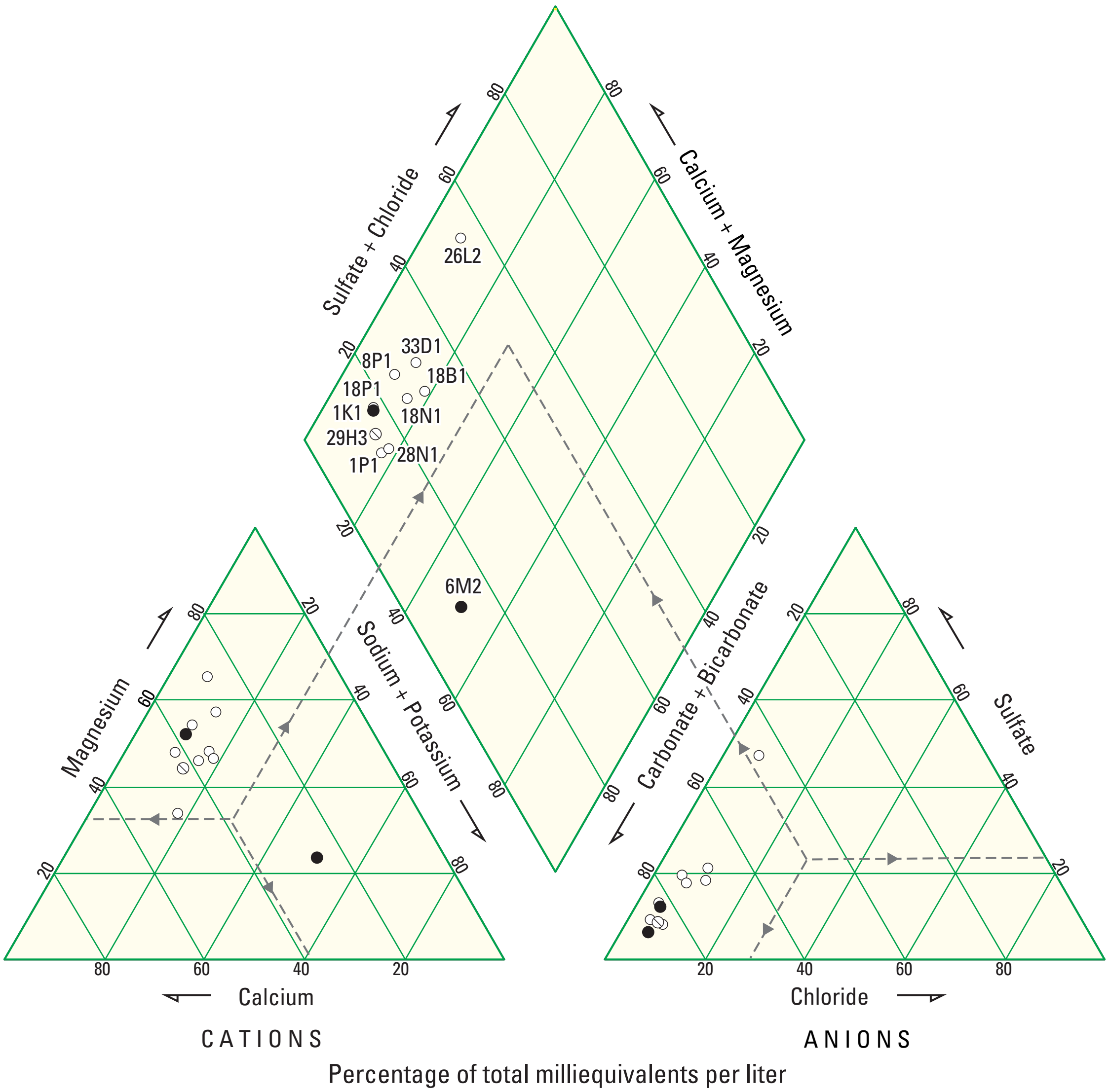


Figure 14.—Continued.



EXPLANATION

Well and identifier—

18N1 Well less than 200 feet deep

6M2 Well greater than 200 feet deep

29H3 Well with unknown depth

Example of how to read a trilinear diagram

Figure 15. Chemical composition of water from selected ground-water sampling sites in the Alexander Valley, Sonoma County, California, 2002–2004.

The composition of most of the historical surface-water samples can be characterized as a mixed cation-bicarbonate type water. Twenty-nine of the 32 samples from the Russian River (station id 11464000) with complete analyses for the period 1951–66 were a mixed-cation-bicarbonate type water (*fig. 14A*). Calcium was the predominant cation in these samples, but in terms of a chemical equivalence basis (milliequivalents per liter, meq/L) calcium constituted less than 50 percent of all cations in each sample. The remaining three samples from the Russian River were a calcium-bicarbonate type water.

The composition of most ground-water samples collected from wells in the Alexander Valley is similar to the composition of the historical surface-water samples from the Russian River near Healdsburg. Thirty-five of 96 historical ground-water samples (*fig. 14A*) and six of 11 recent (2002–2004) ground-water samples (*fig. 15*) were a mixed cation-bicarbonate type water. Magnesium was the predominant cation in about three-fourths of these mixed-bicarbonate samples. Among the other ground-water samples, 33 historical samples from 10 wells (9N/9W-1K1, -1P1; 10N/9W-26L1, -26L2, -33D1; 10N/10W-12G1; 11N/10W-8P1, -28N1, -34D1, and -34D2) (fig. 14*B–D*) and three recent samples from three wells (9N/9W-1K1, 10N/9W-33D1, and 11N/10W-8P1) (*fig. 15*) had a magnesium-bicarbonate composition; a recent sample from one well (10N/9W-26L2) had a magnesium-mixed anion composition (*fig. 15*); 10 historical samples from five wells (9N/9W-1P1; 10N/9W-18R1, -19B1; 11N/10W-28M1 and -28N1) (*figs. 14B–D*) had a calcium-bicarbonate composition; 2 historical samples from one well (11N/10W-33G1) (*fig. 14D*) had a mixed cation-mixed anion composition; 15 historical samples from four wells (9N/8W-7Q1, 10N/9W-32R3, 11N/10W-28M1 and -33A1) (*figs. 14B–D*) and a recent sample from one well (9N/8W-6M2) had a sodium-bicarbonate composition; and a historical sample from one well (11N/10W-33G1) (*fig. 14D*) had a sodium-chloride composition. In summary, nearly three-fourths (72 percent) of historical and recent ground-water samples collected from wells in the Alexander Valley can be characterized as magnesium-bicarbonate or mixed-cation bicarbonate type water with magnesium as the predominant cation.

The spatial distribution of different water types in the Alexander Valley for 2002–04 is illustrated using Stiff diagrams (*fig. 16*). Stiff diagrams plot in an identical sequence the concentration [in milliequivalents per liter (meq/L)] of major cations to the left of zero and major anions to the right of zero (Stiff, 1951). The width of the diagram is an approximate indication of the total ionic content (Hem, 1985). Well 10N/9W-18B1, which was sampled twice during 2002–04 for major ions, is represented by the latest (2004) analyses listed in *Appendix A*. Dissolved-solids concentrations (ROE, residue on evaporation) for ground-water samples collected from 11 wells during 2002–04 ranged from 151 mg/L (11N/10W-28N1) to 551 mg/L (10N/9W-26L2). Stiff diagrams for samples from eight wells (9N/9W-1K1, -1P1; 10N/9W-18B1, -18N1, -18P1, -33D1; 11N/10W-8P1 and -29H3) located from near Cloverdale to south of Jimtown are similar. The similar ionic composition of these water samples suggests a similar source of recharge to these wells, probably a combination of infiltrated precipitation and seepage from the Russian River and its tributaries. The relatively narrow Stiff diagram representing the sample from well 11N/10W-28N1 indicates a total ionic content that is lower than any other sample represented in *figure 16*. The ROE concentration of the sample from well 11N/10W-28N1 was identical to the mean ROE concentration (151 mg/L) of the historical samples collected from the Russian River near Healdsburg (station id 11464000) during 1951–64, suggesting that recharge from the Russian River constitutes the primary source of recharge to this well. Wider Stiff diagrams representing the samples from wells 9N/8W-6M2 and 10N/9W-26L2 are indicative of higher total ionic content. The ROE concentrations of samples from these wells were 381 mg/L and 551 mg/L, respectively, compared with the median value of 254 mg/L for samples from all 11 wells. The higher ionic content of ground water from these wells may be attributed to lithology, well depth, or land use.

Geologic setting and well depth may explain why the water samples from some wells, which plot beyond the main cluster of sample points on the trilinear diagrams (*figs. 14* and *15*), have a distinct ionic composition. Samples from wells 9N/8W-6M2, 9N/8W-7Q1, 9N/9W-4G1, 10N/9W-32R3, 11N/10W-33A1, 11N/10W-33G1, and 11N/10W-33__ have significant proportions of sodium (at least 35 percent, on an equivalent basis, of the total cation balance). These wells are located either in or near geologic units other than Quaternary alluvial deposits, which form the most productive water-bearing unit in the Alexander Valley. Well 11N/10W-33A1 and 11N/10W-33__, located near Asti, were completed in alluvium and alluvial terrace deposits (*fig. 13*) and are less than 200 ft deep. The amount of chloride as a proportion of the total anion balance for samples from well 11N/10W-33A1 ranged from 24 to 57 percent, significantly higher than the mean percentage of chloride (10 percent) in all samples plotted on figures 14 and 15. Wells 9N/8W-6M2, 9N/8W-7Q1, 9N/9W-4G1, and 10N/9W-32R3 are located in the vicinity of Lytton and Jimtown in the southern part of the Alexander Valley and are greater than 200 ft deep. Drillers' logs for these wells indicate the presence of blue clay and conglomerates of clay and gravel, particularly at greater depths. The ionic composition of samples from these wells suggest that ground water in deep wells in the southern part of the Alexander Valley may have higher proportions of sodium and potassium concentrations than water in shallow wells completed in alluvium. Ground water that interacts with clay-bearing aquifer deposits may be modified by cation exchange; for example, sodium cations on the clay minerals are replaced by calcium and magnesium cations, releasing the sodium cations to water (Drever, 1982).

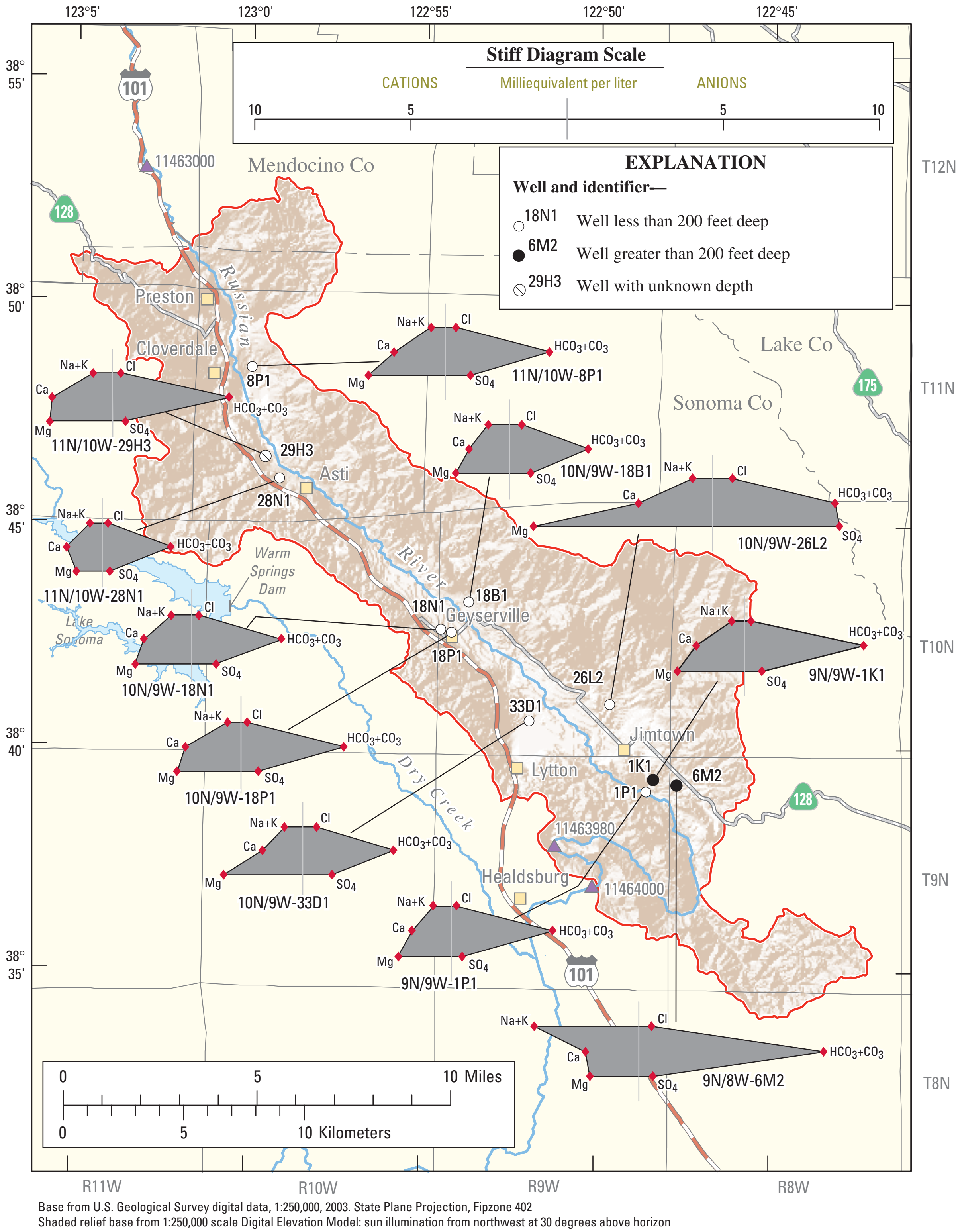
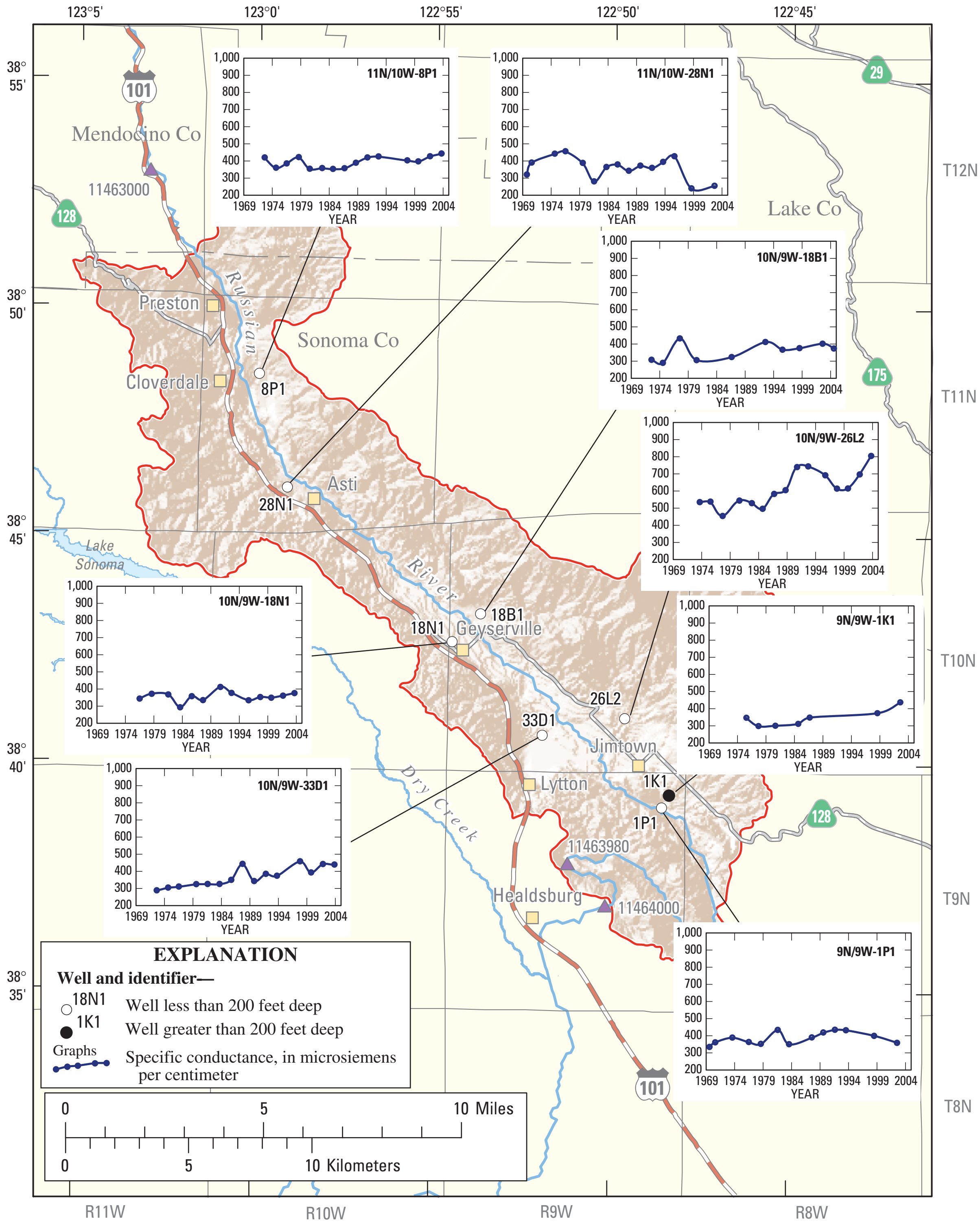


Figure 16. Stiff diagrams showing chemical composition of samples from selected wells in the Alexander Valley, Sonoma County, 2002–04.



Base from U.S. Geological Survey digital data, 1:250,000, 2003. State Plane Projection, Fipzone 402
Shaded relief base from 1:250,000 scale Digital Elevation Model: sun illumination from northwest at 30 degrees above horizon

Figure 17. Time-series plots of electrical conductance for selected ground-water wells in the Alexander Valley, Sonoma County, California, 1969–2004.

As illustrated by *figure 14*, the composition of water from several wells has varied over time. Individual samples collected from shallow (less than 200 ft deep) wells 11N/10W-28M1, -33A1, and -33G1 (fig. 14*D*) had ionic compositions in autumn 1951 (wells -28M1 and -33G1) and spring 1952 (well -33A1) that were markedly different from most of the samples collected from the same wells during 1951–52, 1952–63, and 1951–64, respectively. Cardwell (1965) suggested that the anomalous sodium-bicarbonate (samples from wells -28M1 and -33A1) and sodium-chloride (sample from well -33G1) compositions could be attributed to seasonal variations in the source of water to these wells. Cardwell postulated that underflow from bedrock replaced recharge from precipitation or water from shallow alluvial or colluvial deposits as the source of water to wells 11N/10-28M1 and -33G1. For well 11N/10W-33A1, Cardwell attributed the one-time increase in sodium to recharge from a nearby creek fed by discharge of poor-quality ground water from bedrock.

Water samples from other wells suggest a progressive change in water quality over time that may reflect long-term as opposed to seasonal variations. The ionic composition of samples collected from wells 10N/9W-26L1 (1957–86; fig. 14*C*), -26L2 (1973–2003; *figs. 14C* and *15*), and -33D1 (1972–2003; *figs. 14C* and *15*) show a trend towards higher ionic concentrations and an increasing proportion of sulfate in particular. This long-term trend is also reflected by time-series plots of conductivity. The temporal variation of conductivity in water from eight wells used as long-term monitoring sites by the CADWR is shown on *figure 17*. Time-series plots of conductivity suggest that the most significant changes in water chemistry during 1969–2004 have occurred in the southern part of the Alexander Valley from Geyserville to Lytton and Jimtown. The conductivity at well 10N/9W-26L2 increased 27 percent during the late 1980s and early 1990s, from 583 µS/cm in 1986 to 744 µS/cm in 1992, coinciding with a period of below normal rainfall (1987–92). Conductivity has increased 59 percent at well 10N/9W-33D1, from 288 µS/cm in 1972 to a peak reading of 457 µS/cm in 1997. It cannot be determined on the basis of the limited water-chemistry data whether the increases in conductivity and in concentrations of particular constituents such as sulfate are limited to these particular wells. The reason for the slow degradation of water quality is also unknown, but could be related to localized changes in land use or changes in irrigation practices, including leaching from irrigation. Alternatively, increasing conductivity may reflect an underlying trend toward lesser contribution of lower conductivity water from shallower depths as water levels decline.

Summary and Conclusions

This study was undertaken to update the geohydrologic and geochemical characterization of the Alexander Valley in order to better address surface-water/ground-water-management issues.

The most important sources of ground water in the study area are the Quaternary alluvial deposits, the Glen Ellen Formation, and the Sonoma Volcanics. The alluvial units, where sufficiently thick and saturated, comprise the most productive aquifer in the study area. On most of the valley floor, except immediately adjacent to the bounding hills, the alluvial aquifer generally provides sufficient quantities of water to wells, negating the need to drill into deeper formations. Near the low hills on the valley floor or near the valley sides, the alluvium generally is thinner, and deeper formations are relied upon to provide a part of the total well yield.

Average recharge to the ground-water system for the period 1952–2004 is derived from an estimated average 298,000 acre-ft of precipitation falling within the watershed and from infiltration of part of the water in the Russian River that originates outside of the watershed. Runoff and evapotranspiration from the study area are estimated to be about 160,000 and 113,000 to 133,000 acre-ft/yr, respectively. On the basis of these values, about 5,000 to 25,000 acre-ft/yr is available for ground-water recharge. The estimate of recharge is an order of magnitude smaller than any of the other three main components of the water budget. Because of the relative magnitudes of the values, even a small percentage change in the estimates of precipitation, runoff, or evapotranspiration could result in a large change in the estimate for recharge.

The estimated total water use for the Alexander Valley for 1999 was about 15,800 acre-ft. About 13,500 acre-ft of this amount is agricultural use, predominantly vineyards, and about 2,300 acre-ft is municipal/industrial use. Ground water is the main source of water supply. Some wells are located very close to the Russian River. A better quantification of surface-water diversions and pumpage would be needed to more accurately assess the balance between water use and water supply.

Ground-water-level monitoring in the study area is sparse, with only nine active wells in the California Department of Water Resources network. Long-term changes in ground-water levels are evident in parts of the study area, but because of the sparse network and the lack of data on well construction and lithology, it is uncertain if any significant changes have occurred in the northern part of the study area since 1980. In the southern half of the study area, ground-water levels were generally lower at the end of the irrigation season in 2002 than in 1980, which suggests that a greater amount of ground water is being pumped in the southern half of the study area in recent years compared with that in the early 1980s. The slightly lower water levels measured in spring during recent years compared with those measured in the early 1980s suggests that ground-water use in the southern half of the study area in recent years has been greater than the annual recharge. To more rigorously monitor future changes in the ground-water flow system, a denser water-level monitoring network would be needed.

Water-chemistry data for samples collected from 11 wells during 2002–04 indicate that water quality in the study area generally is acceptable for potable use. The water from two wells, however, each contained one constituent in excess of the recommended standards for drinking water (manganese and boron).

Ground-water composition is a reflection of the source waters and water-rock interactions of the system in which water moves and resides. The chemical composition of water from most of the wells sampled for major ions is a mixed cation-bicarbonate, magnesium-bicarbonate, or calcium-bicarbonate type water. The ionic composition of most historical and recent samples from many wells in the Alexander Valley is similar to that of the historical surface-water samples collected from the Russian River near Healdsburg. This similarity in ionic composition suggests that recharge to most wells, particularly wells that are less than 200 ft total depth and perforated in Quaternary alluvial deposits, may be a combination of infiltration from precipitation and seepage from the Russian River and its tributaries. Recharge to wells that are greater than 200 ft total depth and (or) perforated in geologic units, including continental terrace deposits and clay and gravel conglomerates, consist of slightly more mineralized water as a result of reactions such as cation exchange. These waters generally are characterized by higher concentrations of total dissolved solids and of particular constituents such as sodium.

Water samples collected from several wells over a number of years suggest a progressive change in water chemistry over time. Samples spanning more than 30 years from two wells in the Lytton and Jimtown area show a trend towards higher ionic concentrations and increasing concentrations of particular constituents such as sulfate. These water-quality changes may be attributed to natural processes, such as cation exchange, or to anthropogenic impacts, such as changes in land use or irrigation practices. Water-quality changes in a well also may result from declining water levels, which can reduce the amount of water drawn from shallower depths. Ascertaining the areal extent of these possible water-quality trends and their possible causes will require more comprehensive surface- and ground-water sampling in the Alexander Valley.

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Appendix

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	USGS identification No.	Sample date (mm/dd/yyyy)	Collecting and analyzing agency	Oxygen, dissolved (mg/L) [00300]	pH, field (standard units) [00400]	Specific conductance, field (µS/cm) [00095]
Streamflow-measurement stations						
Russian River at Digger Bend near Healdsburg	11463980	11/05/2003	USGS	[1]11.4	[1]8.5	[1]240
		08/19/2004	USGS	[1]9.0	[1]8.4	[1]256
Russian River near Healdsburg	11464000	05/08/1951	USGS	—	8.1	243
		09/09/1951	USGS	—	8.1	281
		05/19/1952	USGS	—	8.2	241
		10/06/1952	USGS	—	7.9	252
		05/04/1953	USGS	—	7.8	235
		09/14/1953	USGS	—	7.8	238
		05/03/1954	USGS	—	8.2	249
		09/13/1954	USGS	—	7.9	273
		05/02/1955	USGS	—	7.5	234
		09/12/1955	USGS	—	8.2	305
		05/07/1956	USGS	—	7.9	252
		09/11/1956	USGS	—	7.5	287
		05/06/1957	USGS	—	7.8	243
		09/10/1957	USGS	—	8.1	258
		05/09/1958	USGS	—	8.0	273
		09/12/1958	USGS	—	7.8	262
		05/11/1959	USGS	—	8.0	282
		09/04/1959	USGS	—	7.8	234
		05/09/1960	USGS	—	8.1	233
		09/14/1960	USGS	—	8.2	248
		05/03/1961	USGS	—	8.3	237
		09/06/1961	USGS	—	8.0	215
		05/08/1962	USGS	—	7.8	281
		09/11/1962	USGS	—	8.3	243
		05/06/1963	USGS	—	7.9	235
		09/11/1963	USGS	—	8.2	245

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	USGS identification No.	Sample date (mm/dd/yyyy)	Collecting and analyzing agency	Oxygen, dissolved (mg/L) [00300]	pH, field (standard units) [00400]	Specific conduc-tance, field (µS/cm) [00095]
		05/12/1964	USGS	—	7.9	309
		09/02/1964	USGS	—	7.9	257
		05/12/1965	USGS	—	8.2	252
		09/14/1965	USGS	—	8.0	251
		05/03/1966	USGS	—	8.1	262
		09/23/1966	USGS	—	8.0	249
Wells						
9N/8W-6M2	383916122473501	09/27/2004	USGS	0.1	7.4	640
9N/8W-7Q1	—	01/15/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1960	[2] CADWR	—	—	—
		08/21/1961	[2] CADWR	—	—	—
		09/19/1963	[2] CADWR	—	—	—
		09/23/1964	[2] CADWR	—	—	—
		07/08/1969	[2] CADWR	—	8.1	590
		07/16/1980	[2] CADWR	—	8.1	585
9N/8W-18C1	383758122471901	09/15/2004	USGS	—	—	310
9N/9W-1K1	—	06/12/1975	[2] CADWR	—	—	345
		08/28/1986	[2] CADWR	—	7.1	336
		08/27/1998	[2] CADWR	—	7.0	377
		09/18/2002	[2] CADWR	—	7.1	430
9N/9W-1P1	—	01/08/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1960	[2] CADWR	—	—	—
		09/__/1961	[2] CADWR	—	—	—
		09/19/1963	[2] CADWR	—	—	—
		07/08/1969	[2] CADWR	—	7.1	345
		07/26/1973	[2] CADWR	—	7.1	380

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	USGS identification No.	Sample date (mm/dd/yyyy)	Collecting and analyzing agency	Oxygen, dissolved (mg/L) [00300]	pH, field (standard units) [00400]	Specific conductance, field (µS/cm) [00095]
		08/10/1983	[2] CADWR	—	6.9	330
		09/01/1993	[2] CADWR	—	6.4	428
		09/18/2002	[2] CADWR	—	7.2	351
9N/9W-4G1	—	10/23/1951	[2] CADWR	—	—	—
		01/08/1957	[2] CADWR	—	—	—
10N/9W-17D1	384309122531301	09/30/2004	USGS	—	—	488
10N/9W-18B1	—	08/10/1972	[2] CADWR	—	6.7	325
		09/17/1986	[2] CADWR	—	6.3	312
		08/27/1998	[2] CADWR	—	6.6	377
		09/18/2002	[2] CADWR	—	6.8	397
		09/12/2004	[2] CADWR	—	7.7 (L)	382
10N/9W-18N1	—	06/23/1976	[2] CADWR	—	6.7	333
		08/18/1987	[2] CADWR	—	6.8	351
		08/24/1999	[2] CADWR	—	5.7	347
		09/17/2001	[2] CADWR	—	—	—
		09/24/2003	[2] CADWR	—	7.0	375
10N/9W-18P1	384238122541201	09/28/2004	USGS	5.7	6.8	362
10N/9W-18R1	—	01/10/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/19/1963	[2] CADWR	—	—	—
		09/23/1964	[2] CADWR	—	—	—
10N/9W-19B1	—	09/27/1951	[2] CADWR	—	—	—
10N/9W-19C1	—	09/27/1951	[2] CADWR	—	—	—
10N/9W-26L1	—	01/15/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		12/__/1962	[2] CADWR	—	—	—
		09/23/1964	[2] CADWR	—	—	—
		07/08/1969	[2] CADWR	—	7.5	600

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	USGS identification No.	Sample date (mm/dd/yyyy)	Collecting and analyzing agency	Oxygen, dissolved (mg/L) [00300]	pH, field (standard units) [00400]	Specific conductance, field (µS/cm) [00095]
		09/05/1986	[2] CADWR	—	7.2	587
10N/9W-26L2	—	07/25/1973	[2] CADWR	—	6.9	510
		08/17/1984	[2] CADWR	—	6.6	438
		09/17/2001	[2] CADWR	—	—	—
		09/24/2003	[2] CADWR	—	7.2	799
10N/9W-32R3	—	04/02/1952	[2] CADWR	—	—	—
		01/15/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1960	[2] CADWR	—	—	—
10N/9W-33D1	—	08/09/1972	[2] CADWR	—	7.3	300
		08/10/1983	[2] CADWR	—	7.1	312
		09/01/1993	[2] CADWR	—	6.9	377
		09/17/2001	[2] CADWR	—	—	—
		09/24/2003	[2] CADWR	—	7.0	437
10N/10W-12G1	—	06/12/1975	[2] CADWR	—	7.0	390
		08/28/1985	[2] CADWR	—	6.9	339
10N/10W-13K5	—	08/08/1974	[2] CADWR	—	7.3	530
11N/10W-8P1	—	08/09/1972	[2] CADWR	—	7.0	410
		09/22/1982	[2] CADWR	—	6.8	365
		08/25/1992	[2] CADWR	—	7.2	416
		09/17/2001	[2] CADWR	—	—	—
		09/24/2003	[2] CADWR	—	7.0	437
11N/10W-28M1	—	10/19/1951	[2] CADWR	—	—	—
		03/20/1952	[2] CADWR	—	—	—
		04/16/1952	[2] CADWR	—	—	—
11N/10W-28N1	—	01/09/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1961	[2] CADWR	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	USGS identification No.	Sample date (mm/dd/yyyy)	Collecting and analyzing agency	Oxygen, dissolved (mg/L) [00300]	pH, field (standard units) [00400]	Specific conductance, field (µS/cm) [00095]
		09/19/1963	[2] CADWR	—	—	—
		09/23/1964	[2] CADWR	—	—	—
		09/08/1969	[2] CADWR	—	7.3	365
		07/12/1979	[2] CADWR	—	7.1	388
		08/31/1989	[2] CADWR	—	7.0	401
		09/18/2002	[2] CADWR	—	6.9 (L)	252 (L)
11N/10W-29H3	384628122592701	09/29/2004	USGS	0.6	7.2	440
11N/10W-33A1	—	10/19/1951	[2] CADWR	—	—	—
		03/20/1952	[2] CADWR	—	—	—
		04/16/1952	[2] CADWR	—	—	—
		01/09/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1961	[2] CADWR	—	—	—
		09/19/1963	[2] CADWR	—	—	—
11N/10W-33__	—	01/16/1956	[2] CADWR	—	—	—
11N/10W-33G1	—	10/19/1951	[2] CADWR	—	—	—
		03/20/1952	[2] CADWR	—	—	—
		04/17/1952	[2] CADWR	—	—	—
		01/10/1957	[2] CADWR	—	—	—
		07/__/1958	[2] CADWR	—	—	—
		09/__/1959	[2] CADWR	—	—	—
		09/__/1961	[2] CADWR	—	—	—
		09/19/1963	[2] CADWR	—	—	—
		09/23/1964	[2] CADWR	—	—	—
11N/10W-34D1	—	10/18/1951	[2] CADWR	—	—	—
11N/10W-34D2	—	10/18/1951	[2] CADWR	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Temperature, water °C [00010]	Hardness, total (mg/L as $CaCO_3$) [00900]	Calcium, dissolved (mg/L) [00915]	Magnesium, dissolved (mg/L) [00925]	Potassium, dissolved (mg/L) [00935]	Sodium, dissolved (mg/L) [00930]
Streamflow-measurement stations							
Russian River at Digger Bend near Healdsburg	11/05/2003	[1]14.5	—	—	—	—	—
	08/19/2004	[1]25.5	—	—	—	—	—
Russian River near Healdsburg	05/08/1951	—	110	24	13	0.9	6.4
	09/09/1951	—	130	28	15	1	11
	05/19/1952	—	110	22	13	0.9	8.1
	10/06/1952	—	110	26	11	1.1	13
	05/04/1953	—	110	23	12	1.1	8.7
	09/14/1953	—	110	23	12	1	9.2
	05/03/1954	—	110	25	12	0.8	7.8
	09/13/1954	—	110	25	12	1.3	14
	05/02/1955	—	110	25	11	0.9	8.7
	09/12/1955	—	120	28	12	1.2	18
	05/07/1956	—	110	28	9.8	1.2	11
	09/11/1956	—	120	27	14	1.4	14
	05/06/1957	—	120	25	13	0.8	7.8
	09/10/1957	—	120	24	15	1.4	8.7
	05/09/1958	—	130	28	14	1.7	8.6
	09/12/1958	—	120	26	14	1.2	7.4
	05/11/1959	—	130	25	16	1.4	8.4
	09/04/1959	—	110	23	12	1.5	8.5
	05/09/1960	—	110	23	13	1.3	7.3
	09/14/1960	—	110	23	13	1	9.8
	05/03/1961	—	110	23	12	1.4	9.5
	09/06/1961	—	98	24	9.2	1	7
	05/08/1962	—	130	28	15	1.2	9.8
	09/11/1962	—	110	26	12	0.8	8.1
	05/06/1963	—	110	22	14	1.2	6.8
	09/11/1963	—	110	25	13	1	7.4
	05/12/1964	—	140	33	15	1	9.2

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Temperature, water °C [00010]	Hardness, total (mg/L as $CaCO_3$) [00900]	Calcium, dissolved (mg/L) [00915]	Magnesium, dissolved (mg/L) [00925]	Potassium, dissolved (mg/L) [00935]	Sodium, dissolved (mg/L) [00930]
	09/02/1964	—	120	27	13	1	8.8
	05/12/1965	—	120	28	11	1.3	7.4
	09/14/1965	—	120	26	12	1.3	8.3
	05/03/1966	—	120	26	13	1.1	8.8
	09/23/1966	—	120	25	13	1.2	8
Wells							
9N/8W-6M2	09/27/2004	22.0	170	34.5	19.2	1.3	76.7
9N/8W-7Q1	01/15/1957	16	24	3.8	3.5	5.1	75
	07/15/1958	—	16	1	3	4.9	131
	09/15/1959	—	17	4.8	1.2	6.2	134
	09/15/1960	—	15	4	1	4	138
	08/21/1961	—	18	3.7	2.2	5.0	118
	09/19/1963	—	13	3.6	1.0	4.0	132
	09/23/1964	—	12	2.6	1.3	5.4	132
	07/08/1969	27	13	4.1	0.7	5.8	130
	07/16/1980	27	13	2	2	5.3	132
9N/8W-18C1	09/15/2004	18.0	—	—	—	—	—
9N/9W-1K1	06/12/1975	17	162	26	23	0.7	12
	08/28/1986	19	168	26	25	0.8	12
	08/27/1998	19.0	175	29	25	0	13
	09/18/2002	16.5	185	31	26	0.6	9
9N/9W-1P1	01/08/1957	9	203	48	20	1.0	13
	07/__/1958	—	169	28	24	0.3	11
	09/__/1959	—	141	25	19	0.8	12
	09/__/1960	—	148	21	23	1	13
	09/__/1961	—	144	19	23	0.7	10
	09/19/1963	—	122	17	19	0.8	13
	07/08/1969	16	167	28	24	0.5	8.0
	07/26/1973	14	184	30	26	0.6	9.2
	08/10/1983	16	165	28	23	0.6	9

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Temperature, water °C [00010]	Hardness, total (mg/L as $CaCO_3$) [00900]	Calcium, dissolved (mg/L) [00915]	Magnesium, dissolved (mg/L) [00925]	Potassium, dissolved (mg/L) [00935]	Sodium, dissolved (mg/L) [00930]
	09/01/1993	15.6	206	33	30	0.6	10
	09/18/2002	18.5	149	25	21	0.8	13
9N/9W-4G1	10/23/1951	—	110	28	9.8	2.3	34
	01/08/1957	11	114	28	11	1.7	32
10N/9W-17D1	09/30/2004	19.5	—	—	—	—	—
10N/9W-18B1	08/10/1972	17	118	20	16	0.3	17
	09/17/1986	17	129	25	16	0.5	16
	08/27/1998	19.0	151	26	21	0.9	15
	09/18/2002	18.5	156	26	22	0.8	15
	09/12/2004	19.0	151	26	21	0.8	15
10N/9W-18N1	06/23/1976	16	147	26	20	0.6	16
	08/18/1987	17	145	25	20	0.5	16
	08/24/1999	18.1	143	26	19	1	14
	09/17/2001	—	154	27	21	1	13
	09/24/2003	18.5	168	31	22	0.9	14
10N/9W-18P1	09/28/2004	16.5	190	35.7	24.8	0.90	9.06
10N/9W-18R1	01/10/1957	—	153	31	18	1.1	8.5
	07/__/1958	—	169	32	22	0.7	9
	09/__/1959	—	146	29	18	0.9	8.4
	09/19/1963	—	170	31	22	0.7	8.5
	09/23/1964	—	141	34	14	1.2	8.5
10N/9W-19B1	09/27/1951	—	151	44	10	0.4	10
10N/9W-19C1	09/27/1951	—	116	20	16	0.6	11
10N/9W-26L1	01/15/1957	17	242	25	44	0.2	10
	07/__/1958	—	256	28	45	0.3	13
	09/__/1959	—	263	28	47	0.3	12
	12/__/1962	—	265	29	47	0.4	12
	09/23/1964	—	274	22	53	0.4	11
	07/08/1969	18	309	30	57	0.5	11
	09/05/1986	18	325	31	60	0.3	11
10N/9W-26L2	07/25/1973	19	258	30	44	0.1	11

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Temperature, water °C [00010]	Hardness, total (mg/L as $CaCO_3$) [00900]	Calcium, dissolved (mg/L) [00915]	Magnesium, dissolved (mg/L) [00925]	Potassium, dissolved (mg/L) [00935]	Sodium, dissolved (mg/L) [00930]
	08/17/1984	18	246	29	42	0.1	11
	09/17/2001	—	347	40	60	< 0.5	14
	09/24/2003	19.5	406	47	70	<0.5	15
10N/9W-32R3	04/02/1952	17	74	21	5.3	0.8	77
	01/15/1957	19	287	78	22	0.7	72
	07/__/1958	—	130	36	10	0.7	69
	09/__/1959	—	125	37	7.9	3.4	70
	09/__/1960	—	89	20	10	1	71
10N/9W-33D1	08/09/1972	18	128	18	20	0.3	11
	08/10/1983	18	139	21	21	0.9	12
	09/01/1993	18.8	171	24	27	0.8	12
	09/17/2001	—	193	26	31	0.8	12
	09/24/2003	19.5	193	26	31	0.8	13
10N/10W-12G1	06/12/1975	—	193	33	27	0.8	8.8
	08/28/1985	18	160	31	20	0.9	9
10N/10W-13K5	08/08/1974	—	220	44	27	0.7	25
11N/10W-8P1	08/09/1972	—	192	28	30	0.2	10
	09/22/1982	18	166	27	24	0.7	9
	08/25/1992	17.6	208	32	31	0.9	10
	09/17/2001	—	191	32	27	0.7	9
	09/24/2003	18.0	203	32	30	0.9	10
11N/10W-28M1	10/19/1951	—	36	6.8	4.6	0.6	140
	03/20/1952	—	195	42	22	0.7	8.9
	04/16/1952	14	195	45	20	1.1	7.6
11N/10W-28N1	01/09/1957	17	187	30	27	0.6	10
	07/__/1958	—	189	47	17	0.7	12
	09/__/1959	—	199	47	20	1.0	11
	09/__/1961	—	178	43	17	1.0	9.4
	09/19/1963	—	183	44	18	1.0	9.8
	09/23/1964	—	144	28	18	0.9	8.5
	09/08/1969	17	148	32	16	1.3	9.2

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or State well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Temperature, water °C [00010]	Hardness, total (mg/L as $CaCO_3$) [00900]	Calcium, dissolved (mg/L) [00915]	Magnesium, dissolved (mg/L) [00925]	Potassium, dissolved (mg/L) [00935]	Sodium, dissolved (mg/L) [00930]
	07/12/1979	18	184	44	18	1.0	11
	08/31/1989	17	181	43	18	1.0	9
	09/18/2002	—	99	23	10	0.9	9
11N/10W-29H3	09/29/2004	18.0	200	38.4	24.5	0.99	13.3
11N/10W-33A1	10/19/1951	—	135	26	17	0.6	12
	03/20/1952	—	103	20	13	0.7	16
	04/16/1952	—	230	21	43	3.7	145
	01/09/1957	14	153	32	18	0.8	14
	07/__/1958	—	115	23	14	1.0	12
	09/__/1959	—	111	24	12	1.4	11
	09/__/1961	—	103	22	12	1.2	9.2
	09/19/1963	—	165	31	21	1.5	24
11N/10W-33__	01/16/1956	—	103	17	15	0.7	27
11N/10W-33G1	10/19/1951	—	14	4.0	1.0	9.2	112
	03/20/1952	—	55	11	6.7	0.7	15
	04/17/1952	13	61	12	7.5	1.4	17
	01/10/1957	9	54	10	7.1	0.8	15
	07/__/1958	—	65	13	8	1.0	18
	09/__/1959	—	49	9.2	6.3	0.6	16
	09/__/1961	—	59	10	8.3	0.9	15
	09/19/1963	—	50	9.6	6.3	1.6	15
	09/23/1964	—	52	11	6.0	0.7	14
11N/10W-34D1	10/18/1951	—	400	43	71	25	39
11N/10W-34D2	10/18/1951	—	820	139	115	28	41

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Alkalinity, field (mg/L as $CaCO_3$) [29802]	Bicarbonate (mg/L) [00440]	Bromide, dissolved (mg/L) [71870]	Chloride, dissolved (mg/L) [00940]	Fluoride, dissolved mg/L) [00950]	Iodide, dissolved (mg/L) [71865]
Streamflow-measurement stations							
Russian River at Digger Bend near Healdsburg	11/05/2003	—	—	—	—	—	—
	08/19/2004	—	—	—	—	—	—
Russian River near Healdsburg	05/08/1951	—	133	—	4.2	—	—
	09/09/1951	—	162	—	5.5	0	—
	05/19/1952	—	133	—	5.5	0.2	—
	10/06/1952	—	143	—	5.8	0	—
	05/04/1953	—	126	—	5.5	0.2	—
	09/14/1953	—	133	—	5	0	—
	05/03/1954	—	135	—	3.6	0.1	—
	09/13/1954	—	145	—	9.8	0.1	—
	05/02/1955	—	129	—	7.5	0.1	—
	09/12/1955	—	164	—	12	0.1	—
	05/07/1956	—	140	—	4.6	0.3	—
	09/11/1956	—	165	—	9.1	0	—
	05/06/1957	—	138	—	5	0.2	—
	09/10/1957	—	156	—	5.5	0.2	—
	05/09/1958	—	154	—	5	0	—
	09/12/1958	—	148	—	7	0	—
	05/11/1959	—	159	—	7	0.1	—
	09/04/1959	—	136	—	4.2	0	—
	05/09/1960	—	135	—	5	0	—
	09/14/1960	—	143	—	4.8	0.1	—
	05/03/1961	—	130	—	3.8	0.2	—
	09/06/1961	—	120	—	2.2	0.1	—
	05/08/1962	—	153	—	4.5	0	—
	09/11/1962	—	133	—	4	0	—
	05/06/1963	—	137	—	3.8	0.2	—
	09/11/1963	—	141	—	5.8	0.1	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Alkalinity, field (mg/L as $CaCO_3$) [29802]	Bicarbonate (mg/L) [00440]	Bromide, dissolved (mg/L) [71870]	Chloride, dissolved (mg/L) [00940]	Fluoride, dissolved mg/L) [00950]	Iodide, dissolved (mg/L) [71865]
	05/12/1964	—	171	—	8.5	0.2	—
	09/02/1964	—	145	—	4.8	—	—
	05/12/1965	—	137	—	4.2	—	—
	09/14/1965	—	140	—	4	—	—
	05/03/1966	—	145	—	5.2	—	—
	09/23/1966	—	140	—	3.2	—	—
Wells							
9N/8W-6M2	09/27/2004	298	[3]365	0.11	13.2	0.3	0.069
9N/8W-7Q1	01/15/1957	—	218	—	9.9	0.4	—
	07/15/1958	—	308	—	41	0.8	—
	09/15/1959	—	292	—	38	0.9	—
	09/15/1960	—	243	—	42	0.72	—
	08/21/1961	—	287	—	33	0.8	—
	09/19/1963	257	270	—	38	1.0	—
	09/23/1964	251	306	—	36	—	—
	07/08/1969	—	299	—	18	—	—
	07/16/1980	252	[3]307	—	37	—	—
9N/8W-18C1	09/15/2004	—	—	—	—	—	—
9N/9W-1K1	06/12/1975	—	193	—	6	—	—
	08/28/1986	167	[3]204	—	6	—	—
	08/27/1998	162	[3]198	—	6	—	—
	09/18/2002	192	[3]234	—	8	—	—
9N/9W-1P1	01/08/1957	—	255	—	8.5	0	—
	07/__/1958	—	191	—	11	0	—
	09/__/1959	—	172	—	4.8	0.2	—
	09/__/1960	—	170	—	14	0.11	—
	09/__/1961	—	175	—	6.2	0.2	—
	09/19/1963	126	154	—	9.0	0.1	—
	07/08/1969	—	194	—	4.3	—	—
	07/26/1973	—	192	—	6.2	—	—
	08/10/1983	160	[3]195	—	5	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Alkalinity, field (mg/L as $CaCO_3$) [29802]	Bicarbonate (mg/L) [00440]	Bromide, dissolved (mg/L) [71870]	Chloride, dissolved (mg/L) [00940]	Fluoride, dissolved mg/L) [00950]	Iodide, dissolved (mg/L) [71865]
	09/01/1993	174	[3]212	—	9	—	—
	09/18/2002	162	[3]198	—	6	—	—
9N/9W-4G1	10/23/1951	—	208	—	10	0	—
	01/08/1957	—	206	—	15	0	—
10N/9W-17D1	09/30/2004	—	—	—	—	—	—
10N/9W-18B1	08/10/1972	—	125	—	12	—	—
	09/17/1986	91	[3]111	—	17	—	—
	08/27/1998	139	[3]170	—	13	—	—
	09/18/2002	148	[3]180	—	15	—	—
	09/12/2004	126	[3]154	—	14	—	—
10N/9W-18N1	06/23/1976	—	151	—	7.6	—	—
	08/18/1987	122	[3]149	—	6	—	—
	08/24/1999	125	[3]152	—	6	—	—
	09/17/2001	135	[3]165	—	8	—	—
	09/24/2003	144	[3]176	—	8	—	—
10N/9W-18P1	09/28/2004	167	[3]204	0.17	5.94	<0.2	E0.001
10N/9W-18R1	01/10/1957	—	184	—	8.4	0	—
	07/__/1958	—	204	—	5	0	—
	09/__/1959	—	170	—	4.8	0.1	—
	09/19/1963	156	170	—	6.5	0.1	—
	09/23/1964	136	150	—	4.5	—	—
10N/9W-19B1	09/27/1951	—	170	—	6.0	0.1	—
10N/9W-19C1	09/27/1951	—	122	—	8.0	0.1	—
10N/9W-26L1	01/15/1957	—	282	—	7.2	0.1	—
	07/__/1958	—	281	—	14	0.2	—
	09/__/1959	—	278	—	5.8	0	—
	12/__/1962	—	300	—	8.3	0.2	—
	09/23/1964	252	275	—	7.0	—	—
	07/08/1969	—	310	—	8.0	—	—
	09/05/1986	276	[3]337	—	11	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Alkalinity, field (mg/L as $CaCO_3$) [29802]	Bicarbonate (mg/L) [00440]	Bromide, dissolved (mg/L) [71870]	Chloride, dissolved (mg/L) [00940]	Fluoride, dissolved mg/L) [00950]	Iodide, dissolved (mg/L) [71865]
10N/9W-26L2	07/25/1973	—	193	—	10	—	—
	08/17/1984	208	[3]254	—	7	—	—
	09/17/2001	202	[3]246	—	23	—	—
	09/24/2003	196	[3]239	—	22	—	—
10N/9W-32R3	04/02/1952	—	247	—	8.2	0.8	—
	01/15/1957	—	488	—	12	0.5	—
	07/__/1958	—	294	—	15	0.5	—
	09/__/1959	—	289	—	12	0.4	—
	09/__/1960	—	234	—	13	0.90	—
10N/9W-33D1	08/09/1972	—	150	—	8.3	—	—
	08/10/1983	131	[3]160	—	8	—	—
	09/01/1993	137	[3]167	—	10	—	—
	09/17/2001	145	[3]177	—	14	—	—
	09/24/2003	146	[3]178	—	15	—	—
10N/10W-12G1	06/12/1975	—	236	—	0.0	—	—
	08/28/1985	162	[3]198	—	4	—	—
10N/10W-13K5	08/08/1974	—	309	—	3.8	—	—
11N/10W-8P1	08/09/1972	—	177	—	8.8	—	—
	09/22/1982	139	[3]170	—	5	—	—
	08/25/1992	148	[3]180	—	12	—	—
	09/17/2001	159	[3]194	—	11	—	—
	09/24/2003	168	[3]205	—	12	—	—
11N/10W-28M1	10/19/1951	—	384	—	20	0.1	—
	03/20/1952	—	218	—	5.8	0	—
	04/16/1952	—	237	—	3.0	0	—
11N/10W-28N1	01/09/1957	—	226	—	5.7	0.0	—
	07/__/1958	—	235	—	12	0.2	—
	09/__/1959	—	246	—	8.4	0.0	—
	09/__/1961	—	222	—	4.6	0.0	—
	09/19/1963	185	222	—	7.5	0.1	—
	09/23/1964	148	180	—	4.2	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Alkalinity, field (mg/L as $CaCO_3$) [29802]	Bicarbonate (mg/L) [00440]	Bromide, dissolved (mg/L) [71870]	Chloride, dissolved (mg/L) [00940]	Fluoride, dissolved mg/L) [00950]	Iodide, dissolved (mg/L) [71865]
	09/08/1969	—	181	—	4.9	—	—
	07/12/1979	167	[3]204	—	9	—	—
	08/31/1989	182	[3]222	—	5	—	—
	09/18/2002	110	[3]134	—	7	—	—
11N/10W-29H3	09/29/2004	189	[3]232	0.07	9.82	<0.2	0.007
11N/10W-33A1	10/19/1951	—	157	—	14	0	—
	03/20/1952	—	142	—	7.5	0	—
	04/16/1952	—	546	—	78	0.0	—
	01/09/1957	—	195	—	10	0.0	—
	07/__/1958	—	147	—	13	0.2	—
	09/__/1959	—	144	—	7.5	0.2	—
	09/__/1961	—	134	—	4.6	0.1	—
	09/19/1963	177	206	—	18	0.1	—
11N/10W-33__	01/16/1956	—	159	—	13	0	—
11N/10W-33G1	10/19/1951	—	133	—	110	0.8	—
	03/20/1952	—	53	—	13	0	—
	04/17/1952	—	57	—	20	0.0	—
	01/10/1957	—	61	—	21	0.0	—
	07/__/1958	—	63	—	30	0	—
	09/__/1959	—	40	—	24	0.0	—
	09/__/1961	—	55	—	21	0.1	—
	09/19/1963	39	47	—	18	0.1	—
	09/23/1964	45	55	—	17	—	—
11N/10W-34D1	10/18/1951	—	572	—	20	0.1	—
11N/10W-34D2	10/18/1951	—	1,090	—	29	0	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Silica, dissolved (mg/L) [00955]	Sulfate, dissolved (mg/L) [00945]	Solids, sum of constituents, dissolved (mg/L) [70301]	Solids, residue on evaporation at 180°C (mg/L) [70300]	Nitrogen, ammonia, dissolved (mg/L) [00608]	Nitrite plus nitrate as N, dissolved (mg/L) [00631]
Streamflow-measurement stations							
Russian River at Digger Bend near Healdsburg	11/05/2003	—	—	—	—	—	—
	08/19/2004	—	—	—	—	—	—
Russian River near Healdsburg	05/08/1951	16	14	145	—	—	—
	09/09/1951	14	12	166	—	—	—
	05/19/1952	23	11	150	—	—	—
	10/06/1952	9.8	8.3	146	—	—	—
	05/04/1953	16	12	142	—	—	—
	09/14/1953	14	9.6	140	—	—	—
	05/03/1954	14	11	141	—	—	—
	09/13/1954	13	9.3	159	—	—	—
	05/02/1955	5.6	13	137	—	—	—
	09/12/1955	12	7.8	176	—	—	—
	05/07/1956	16	12	154	—	—	—
	09/11/1956	17	8.1	174	—	—	—
	05/06/1957	18	12	151	—	—	—
	09/10/1957	18	2.9	153	—	—	—
	05/09/1958	19	12	165	—	—	—
	09/12/1958	13	7.7	151	—	—	—
	05/11/1959	13	8.6	160	—	—	—
	09/04/1959	11	7.2	135	—	—	—
	05/09/1960	15	11	144	—	—	—
	09/14/1960	17	9	148	—	—	—
	05/03/1961	13	11	140	—	—	—
	09/06/1961	12	7	123	—	—	—
	05/08/1962	15	15	166	—	—	—
	09/11/1962	12	10	141	—	—	—
	05/06/1963	21	11	149	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Silica, dissolved (mg/L) [00955]	Sulfate, dissolved (mg/L) [00945]	Solids, sum of constituents, dissolved (mg/L) [70301]	Solids, residue on evaporation at 180°C (mg/L) [70300]	Nitrogen, ammonia, dissolved (mg/L) [00608]	Nitrite plus nitrate as N, dissolved (mg/L) [00631]
	09/11/1963	15	9	146	—	—	—
	05/12/1964	12	15	179	—	—	—
	09/02/1964	12	11	150	—	—	—
	05/12/1965	14	14	148	153	—	—
	09/14/1965	13	10	144	148	—	—
	05/03/1966	13	14	153	154	—	—
	09/23/1966	13	11	144	146	—	—
Wells							
9N/8W-6M2	09/27/2004	38.1	21.7	385	381	0.16	E0.04
9N/8W-7Q1	01/15/1957	72	2.1	279	—	—	—
	07/15/1958	41	0	—	444	—	—
	09/15/1959	74	1.0	—	—	—	—
	09/15/1960	55	1	401	—	—	—
	08/21/1961	95	0.0	400	—	—	—
	09/19/1963	83	1.0	—	416	—	—
	09/23/1964	—	1.0	—	425	—	—
	07/08/1969	—	0.5	—	402	—	—
	07/16/1980	—	0	—	436	—	—
9N/8W-18C1	09/15/2004	—	—	—	—	—	—
9N/9W-1K1	06/12/1975	—	18	—	209	—	—
	08/28/1986	—	15	—	201	—	—
	08/27/1998	—	26	—	214	—	—
	09/18/2002	—	28	—	262	—	—
9N/9W-1P1	01/08/1957	18	5.8	242	—	—	—
	07/__/1958	24	14	—	274	—	—
	09/__/1959	28	11	195	—	—	—
	09/__/1960	19	13	190	—	—	—
	09/__/1961	16	12	175	—	—	—
	09/19/1963	36	5	—	179	—	—
	07/08/1969	—	18	—	150	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Silica, dissolved (mg/L) [00955]	Sulfate, dissolved (mg/L) [00945]	Solids, sum of constituents, dissolved (mg/L) [70301]	Solids, residue on evaporation at 180°C (mg/L) [70300]	Nitrogen, ammonia, dissolved (mg/L) [00608]	Nitrite plus nitrate as N, dissolved (mg/L) [00631]
	07/26/1973	—	28	—	215	—	—
	08/10/1983	—	18	—	204	—	—
	09/01/1993	—	34	—	244	—	—
	09/18/2002	—	17	—	215	—	—
9N/9W-4G1	10/23/1951	30	3.0	220	—	—	—
	01/08/1957	31	1.0	222	—	—	—
10N/9W-17D1	09/30/2004	—	—	—	—	—	—
10N/9W-18B1	08/10/1972	—	18	—	187	—	—
	09/17/1986	—	31	—	212	—	—
	08/27/1998	—	29	—	—	—	—
	09/18/2002	—	27	—	240	—	—
	09/12/2004	—	32	—	215	—	—
10N/9W-18N1	06/23/1976	25	38	—	228	—	—
	08/18/1987	—	35	—	211	—	—
	08/24/1999	—	33	—	210	—	—
	09/17/2001	—	33	—	224	—	—
	09/24/2003	—	35	—	226	—	—
10N/9W-18P1	09/28/2004	24.9	26.2	237	231	<0.04	1.89
10N/9W-18R1	01/10/1957	19	9.6	189	—	—	—
	07/__/1958	7	6	—	254	—	—
	09/__/1959	21	13	—	—	—	—
	09/19/1963	25	13	—	202	—	—
	09/23/1964	—	13	—	154	—	—
10N/9W-19B1	09/27/1951	18	18	198	—	—	—
10N/9W-19C1	09/27/1951	25	23	173	—	—	—
10N/9W-26L1	01/15/1957	36	13	288	—	—	—
	07/__/1958	35	11	—	384	—	—
	09/__/1959	39	11	—	307	—	—
	12/__/1962	38	12	313	—	—	—
	09/23/1964	—	16	—	325	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Silica, dissolved (mg/L) [00955]	Sulfate, dissolved (mg/L) [00945]	Solids, sum of constituents, dissolved (mg/L) [70301]	Solids, residue on evaporation at 180°C (mg/L) [70300]	Nitrogen, ammonia, dissolved (mg/L) [00608]	Nitrite plus nitrate as N, dissolved (mg/L) [00631]
	07/08/1969	—	32	—	307	—	—
	09/05/1986	—	43	—	378	—	—
10N/9W-26L2	07/25/1973	—	73	—	322	—	—
	08/17/1984	—	51	—	305	—	—
	09/17/2001	—	135	—	464	—	—
	09/24/2003	—	196	—	551	—	—
10N/9W-32R3	04/02/1952	52	8.1	306	—	—	—
	01/15/1957	43	23	492	—	—	—
	07/__/1958	38	16	—	364	—	—
	09/__/1959	51	24	350	—	—	—
	09/__/1960	34	25	292	—	—	—
10N/9W-33D1	08/09/1972	—	13	—	162	—	—
	08/10/1983	—	21	—	190	—	—
	09/01/1993	—	33	—	215	—	—
	09/17/2001	—	45	—	274	—	—
	09/24/2003	—	44	—	258	—	—
10N/10W-12G1	06/12/1975	—	12	—	219	—	—
	08/28/1985	—	15	—	189	—	—
10N/10W-13K5	08/08/1974	—	15	—	313	—	—
11N/10W-8P1	08/09/1972	—	40	—	254	—	—
	09/22/1982	—	30	—	217	—	—
	08/25/1992	—	37	—	246	—	—
	09/17/2001	—	39	—	262	—	—
	09/24/2003	—	39	—	257	—	—
11N/10W-28M1	10/19/1951	30	14	409	—	—	—
	03/20/1952	15	13	231	—	—	—
	04/16/1952	16	13	224	—	—	—
11N/10W-28N1	01/09/1957	25	14	229	—	—	—
	07/__/1958	14	9	—	304	—	—
	09/__/1959	19	12	240	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Silica, dissolved (mg/L) [00955]	Sulfate, dissolved (mg/L) [00945]	Solids, sum of constituents, dissolved (mg/L) [70301]	Solids, residue on evaporation at 180°C (mg/L) [70300]	Nitrogen, ammonia, dissolved (mg/L) [00608]	Nitrite plus nitrate as N, dissolved (mg/L) [00631]
	09/__/1961	21	9.4	215	—	—	—
	09/19/1963	20	12	—	229	—	—
	09/23/1964	—	1.0	—	194	—	—
	09/08/1969	—	17	—	161	—	—
	07/12/1979	—	23	—	228	—	—
	08/31/1989	—	15	—	216	—	—
	09/18/2002	—	11	—	151	—	—
11N/10W-29H3	09/29/2004	24.8	19.1	249	254	<0.04	0.62
11N/10W-33A1	10/19/1951	65	8.8	224	—	—	—
	03/20/1952	16	9.4	156	—	—	—
	04/16/1952	46	7.2	613	—	—	—
	01/09/1957	11	8.6	193	—	—	—
	07/__/1958	27	5	—	204	—	—
	09/__/1959	19	9.0	156	—	—	—
	09/__/1961	17	5.1	139	—	—	—
	09/19/1963	82	9.0	—	298	—	—
11N/10W-33__	01/16/1956	24	7.8	—	—	—	—
11N/10W-33G1	10/19/1951	76	9.3	391	—	—	—
	03/20/1952	31	14	—	132	—	—
	04/17/1952	33	13	—	144	—	—
	01/10/1957	35	1.0	—	127	—	—
	07/__/1958	19	7	—	164	—	—
	09/__/1959	35	4.0	129	—	—	—
	09/__/1961	36	4.4	143	—	—	—
	09/19/1963	38	3.0	—	138	—	—
	09/23/1964	—	1.0	—	130	—	—
11N/10W-34D1	10/18/1951	31	1.3	518	—	—	—
11N/10W-34D2	10/18/1951	24	3.3	934	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Nitrate as NO_3, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L) [00613]	Phosphorus, ortho-phosphate, dissolved (mg/L) [00671]	Arsenic, dissolved (µg/L) [01000]	Barium, dissolved (µg/L) [01005]
Streamflow-measurement stations						
Russian River at Digger Bend near Healdsburg	11/05/2003	—	—	—	—	—
	08/19/2004	—	—	—	—	—
Russian River near Healdsburg	05/08/1951	—	—	—	—	—
	09/09/1951	—	—	—	—	—
	05/19/1952	—	—	—	—	—
	10/06/1952	—	—	—	—	—
	05/04/1953	—	—	—	—	—
	09/14/1953	—	—	—	—	—
	05/03/1954	—	—	—	—	—
	09/13/1954	—	—	—	—	—
	05/02/1955	—	—	—	—	—
	09/12/1955	—	—	—	—	—
	05/07/1956	—	—	—	—	—
	09/11/1956	—	—	—	—	—
	05/06/1957	—	—	—	—	—
	09/10/1957	—	—	—	—	—
	05/09/1958	—	—	—	—	—
	09/12/1958	—	—	—	—	—
	05/11/1959	—	—	—	—	—
	09/04/1959	—	—	—	—	—
	05/09/1960	—	—	—	—	—
	09/14/1960	—	—	—	—	—
	05/03/1961	—	—	—	—	—
	09/06/1961	—	—	—	—	—
	05/08/1962	—	—	—	—	—
	09/11/1962	—	—	—	—	—
	05/06/1963	—	—	—	—	—
	09/11/1963	—	—	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Nitrate as NO_3, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L) [00613]	Phosphorus, ortho-phosphate, dissolved (mg/L) [00671]	Arsenic, dissolved (µg/L) [01000]	Barium, dissolved (µg/L) [01005]
	05/12/1964	—	—	—	—	—
	09/02/1964	—	—	—	—	—
	05/12/1965	—	—	—	—	—
	09/14/1965	—	—	—	—	—
	05/03/1966	—	—	—	—	—
	09/23/1966	—	—	—	—	—
Wells						
9N/8W-6M2	09/27/2004	[4] E0.2	<0.008	0.09	1.5	247
9N/8W-7Q1	01/15/1957	0.2	—	—	—	—
	07/15/1958	0	—	—	—	—
	09/15/1959	0.2	—	—	—	—
	09/15/1960	0	—	—	—	—
	08/21/1961	0.5	—	—	—	—
	09/19/1963	1.0	—	—	—	—
	09/23/1964	0.3	—	—	—	—
	07/08/1969	1.2	—	—	—	—
	07/16/1980	0.0	—	—	—	—
9N/8W/-18C1	09/15/2004	—	—	—	—	—
9N/9W-1K1	06/12/1975	2.4	—	—	0	—
	08/28/1986	0.6	—	—	—	—
	08/27/1998	3	—	—	—	—
	09/18/2002	2.1	—	—	—	—
9N/9W-1P1	01/08/1957	0.1	—	—	—	—
	07/__/1958	10	—	—	—	—
	09/__/1959	4.8	—	—	—	—
	09/__/1960	1	—	—	—	—
	09/__/1961	2.1	—	—	—	—
	09/19/1963	5	—	—	—	—
	07/08/1969	4.2	—	—	—	—
	07/26/1973	9.8	—	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Nitrate as NO_3, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L) [00613]	Phosphorus, ortho-phosphate, dissolved (mg/L) [00671]	Arsenic, dissolved (µg/L) [01000]	Barium, dissolved (µg/L) [01005]
	08/10/1983	2.3	—	—	—	—
	09/01/1993	9.1	—	—	—	—
	09/18/2002	2	—	—	—	—
9N/9W-4G1	10/23/1951	0.0	—	—	—	—
	01/08/1957	0.8	—	—	—	—
10N/9W-17D1	09/30/2004	—	—	—	—	—
10N/9W-18B1	08/10/1972	22	—	—	—	—
	09/17/1986	14	—	—	—	—
	08/27/1998	9.5	—	—	—	—
	09/18/2002	10.1	—	—	—	—
	09/12/2004	10.8	—	—	—	—
10N/9W-18N1	06/23/1976	9.0	—	—	—	—
	08/18/1987	6.9	—	—	—	—
	08/24/1999	8.6	—	—	—	—
	09/17/2001	9.7	—	—	—	—
	09/24/2003	10.9	—	—	—	—
10N/9W-18P1	09/28/2004	[4] 8.5	<0.008	0.01	E0.1	172
10N/9W-18R1	01/10/1957	0.8	—	—	—	—
	07/__/1958	2	—	—	—	—
	09/__/1959	5.3	—	—	—	—
	09/19/1963	5.6	—	—	—	—
	09/23/1964	0.2	—	—	—	—
10N/9W-19B1	09/27/1951	8.3	—	—	—	—
10N/9W-19C1	09/27/1951	9.1	—	—	—	—
10N/9W-26L1	01/15/1957	13	—	—	—	—
	07/__/1958	14	—	—	—	—
	09/__/1959	13	—	—	—	—
	12/__/1962	13	—	—	—	—
	09/23/1964	13	—	—	—	—
	07/08/1969	19	—	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Nitrate as NO_3, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L) [00613]	Phosphorus, ortho-phosphate, dissolved (mg/L) [00671]	Arsenic, dissolved (µg/L) [01000]	Barium, dissolved (µg/L) [01005]
	09/05/1986	8.8	—	—	—	—
10N/9W-26L2	07/25/1973	37	—	—	—	—
	08/17/1984	4.9	—	—	—	—
	09/17/2001	12.1	—	—	—	—
	09/24/2003	13.6	—	—	—	—
10N/9W-32R3	04/02/1952	0	—	—	—	—
	01/15/1957	0.3	—	—	—	—
	07/__/1958	0	—	—	—	—
	09/__/1959	1.6	—	—	—	—
	09/__/1960	0	—	—	—	—
10N/9W-33D1	08/09/1972	7.7	—	—	—	—
	08/10/1983	8.8	—	—	—	—
	09/01/1993	14	—	—	—	—
	09/17/2001	20.7	—	—	—	—
	09/24/2003	21.8	—	—	—	—
10N/10W-12G1	06/12/1975	1.1	—	—	—	—
	08/28/1985	1.0	—	—	—	—
10N/10W-13K5	08/08/1974	1.6	—	—	0	—
11N/10W-8P1	08/09/1972	18	—	—	—	—
	09/22/1982	14	—	—	—	—
	08/25/1992	22	—	—	—	—
	09/17/2001	13.7	—	—	—	—
	09/24/2003	15.4	—	—	—	—
11N/10W-28M1	10/19/1951	0.4	—	—	—	—
	03/20/1952	16	—	—	—	—
	04/16/1952	1.5	—	—	—	—
11N/10W-28N1	01/09/1957	5.9	—	—	—	—
	07/__/1958	0	—	—	—	—
	09/__/1959	0.2	—	—	—	—
	09/__/1961	0.6	—	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Nitrate as NO_3, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L) [00613]	Phosphorus, ortho-phosphate, dissolved (mg/L) [00671]	Arsenic, dissolved (µg/L) [01000]	Barium, dissolved (µg/L) [01005]
	09/19/1963	1.4	—	—	—	—
	09/23/1964	0.3	—	—	—	—
	09/08/1969	0.5	—	—	—	—
	07/12/1979	4.0	—	—	—	—
	08/31/1989	0.3	—	—	—	—
	09/18/2002	0.8	—	—	—	—
11N/10W-29H3	09/29/2004	[4]2.8	<0.008	0.03	0.5	203
11N/10W-33A1	10/19/1951	0.4	—	—	—	—
	03/20/1952	1.3	—	—	—	—
	04/16/1952	0.1	—	—	—	—
	01/09/1957	0.7	—	—	—	—
	07/__/1958	0	—	—	—	—
	09/__/1959	0.6	—	—	—	—
	09/__/1961	0.8	—	—	—	—
	09/19/1963	0.9	—	—	—	—
11N/10W-33__	01/16/1956	0	—	—	—	—
11N/10W-33G1	10/19/1951	0.3	—	—	—	—
	03/20/1952	14	—	—	—	—
	04/17/1952	12	—	—	—	—
	01/10/1957	6.6	—	—	—	—
	07/__/1958	11	—	—	—	—
	09/__/1959	14	—	—	—	—
	09/__/1961	20	—	—	—	—
	09/19/1963	25	—	—	—	—
	09/23/1964	14	—	—	—	—
11N/10W-34D1	10/18/1951	4.2	—	—	—	—
11N/10W-34D2	10/18/1951	14	—	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Boron, dissolved (µg/L) [01020]	Iron, dissolved (µg/L) [01046]	Lithium, dissolved (µg/L) [01130]	Manganese, dissolved (µg/L) [01056]
Streamflow-measurement stations					
Russian River at Digger Bend near Healdsburg	11/05/2003	—	—	—	—
	08/19/2004	—	—	—	—
Russian River near Healdsburg	05/08/1951	590	—	—	—
	09/09/1951	670	—	—	—
	05/19/1952	650	0	—	—
	10/06/1952	860	0	—	—
	05/04/1953	340	0	—	—
	09/14/1953	930	20	—	—
	05/03/1954	380	10	—	—
	09/13/1954	[5]2,900	10	—	—
	05/02/1955	160	—	—	—
	09/12/1955	[5]3,500	20	—	—
	05/07/1956	[5]1,200	20	—	—
	09/11/1956	[5]2,100	0	—	—
	05/06/1957	280	10	—	—
	09/10/1957	540	0	—	—
	05/09/1958	170	0	—	—
	09/12/1958	800	0	—	—
	05/11/1959	500	20	—	—
	09/04/1959	400	30	—	—
	05/09/1960	300	20	—	—
	09/14/1960	500	0	—	—
	05/03/1961	300	20	—	—
	09/06/1961	400	—	—	—
	05/08/1962	300	—	—	—
	09/11/1962	400	—	—	—
	05/06/1963	200	—	—	—
	09/11/1963	300	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

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Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Boron, dissolved (µg/L) [01020]	Iron, dissolved (µg/L) [01046]	Lithium, dissolved (µg/L) [01130]	Manganese, dissolved (µg/L) [01056]
	05/12/1964	500	—	—	—
	09/02/1964	500	—	—	—
	05/12/1965	300	—	—	—
	09/14/1965	200	—	—	—
	05/03/1966	300	—	—	—
	09/23/1966	400	—	—	—
Wells					
9N/8W-6M2	09/27/2004	120	21	14.6	[6]241
9N/8W-7Q1	01/15/1957	170	—	—	—
	07/15/1958	340	20	—	—
	09/15/1959	400	—	—	—
	09/15/1960	420	—	—	—
	08/21/1961	320	[7]120	—	—
	09/19/1963	400	—	—	—
	09/23/1964	300	20	—	—
	07/08/1969	500	—	—	—
	07/16/1980	500	—	—	—
9N/8W-18C1	09/15/2004	—	—	—	—
9N/9W-1K1	06/12/1975	0	[7]20	—	[8]0
	08/28/1986	100	—	—	—
	08/27/1998	100	—	—	—
	09/18/2002	<100	—	—	—
9N/9W-1P1	01/08/1957	[5]1,300	—	—	—
	07/__/1958	100	30	—	—
	09/__/1959	0	—	—	—
	09/__/1960	0	—	—	—
	09/__/1961	90	[6,7]3,600	—	—
	09/19/1963	0	—	—	—
	07/08/1969	100	—	—	—
	07/26/1973	0	—	—	—
	08/10/1983	100	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Boron, dissolved (µg/L) [01020]	Iron, dissolved (µg/L) [01046]	Lithium, dissolved (µg/L) [01130]	Manganese, dissolved (µg/L) [01056]
	09/01/1993	<100	—	—	—
	09/18/2002	100	—	—	—
9N/9W-4G1	10/23/1951	50	—	—	—
	01/08/1957	120	—	—	—
10N/9W-17D1	09/30/2004	—	—	—	—
10N/9W-18B1	08/10/1972	0	—	—	—
	09/17/1986	100	—	—	—
	08/27/1998	100	—	—	—
	09/18/2002	100	—	—	—
	09/12/2004	100	—	—	—
10N/9W-18N1	06/23/1976	100	—	—	—
	08/18/1987	100	—	—	—
	08/24/1999	100	—	—	—
	09/17/2001	100	—	—	—
	09/24/2003	200	—	—	—
10N/9W-18P1	09/28/2004	260	<6.0	6.5	E0.1
10N/9W-18R1	01/10/1957	[5]1,800	—	—	—
	07/__/1958	700	0	—	—
	09/__/1959	500	—	—	—
	09/19/1963	400	—	—	—
	09/23/1964	400	20	—	—
10N/9W-19B1	09/27/1951	180	—	—	—
10N/9W-19C1	09/27/1951	150	—	—	—
10N/9W-26L1	01/15/1957	130	—	—	—
	07/__/1958	10	10	—	—
	09/__/1959	0	—	—	—
	12/__/1962	170	[7]20	—	—
	09/23/1964	500	10	—	—
	07/08/1969	100	—	—	—
	09/05/1986	100	—	—	—
10N/9W-26L2	07/25/1973	100	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Boron, dissolved (µg/L) [01020]	Iron, dissolved (µg/L) [01046]	Lithium, dissolved (µg/L) [01130]	Manganese, dissolved (µg/L) [01056]
	08/17/1984	100	—	—	—
	09/17/2001	100	—	—	—
	09/24/2003	100	—	—	—
10N/9W-32R3	04/02/1952	590	—	—	—
	01/15/1957	280	—	—	—
	07/__/1958	620	10	—	—
	09/__/1959	400	—	—	—
	09/__/1960	0	—	—	—
10N/9W-33D1	08/09/1972	0	—	—	—
	08/10/1983	200	—	—	—
	09/01/1993	<100	—	—	—
	09/17/2001	<100	—	—	—
	09/24/2003	<100	—	—	—
10N/10W-12G1	06/12/1975	200	—	—	—
	08/28/1985	500	—	—	—
10N/10W-13K5	08/08/1974	100	[7]1,300	—	[8]190
11N/10W-8P1	08/09/1972	400	—	—	—
	09/22/1982	400	—	—	—
	08/25/1992	300	—	—	—
	09/17/2001	300	—	—	—
	09/24/2003	300	—	—	—
11N/10W-28M1	10/19/1951	[5]2,900	—	—	—
	03/20/1952	480	—	—	—
	04/16/1952	240	—	—	—
11N/10W-28N1	01/09/1957	120	—	—	—
	07/__/1958	350	10	—	—
	09/__/1959	200	—	—	—
	09/__/1961	290	[7]20	—	—
	09/19/1963	300	—	—	—
	09/23/1964	400	20	—	—
	09/08/1969	300	—	—	—

See footnotes at end of table.

Appendix A. Field measurements and laboratory analyses of samples from streamflow-measurement stations and ground-water wells, Alexander Valley, Sonoma County, California, 1951–2004—Continued.

[See figure 13 for location of streamflow/measurement stations, and wells. USGS (U.S. Geological Survey) identification number: the unique number for each site in USGS NWIS (National Water Information System) database. Collecting and analyzing agency: USGS, U.S. Geological Survey; CADWR, California Department of Water Resources. Parameter code, in brackets, is a five-digit number in the USGS computerized data system, National Water Information System (NWIS), used to uniquely identify a specific constituent or property. CADWR conductance measurements are referred to as electrical conductance (EC). CADWR alkalinities are laboratory values. $CaCO_3$, calcium carbonate; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; E, value estimated by the USGS National Water Quality Laboratory, Denver Colorado; (L), measured in laboratory; mm/dd/yyyy, month/day/year; <, actual value is less than value shown; —, no data]

Stream site identifier or state well No. (abbreviated or local identifier)	Sample date (mm/dd/yyyy)	Boron, dissolved (µg/L) [01020]	Iron, dissolved (µg/L) [01046]	Lithium, dissolved (µg/L) [01130]	Manganese, dissolved (µg/L) [01056]
	07/12/1979	800	—	—	—
	08/31/1989	200	—	—	—
	09/18/2002	300	—	—	—
11N/10W-29H3	09/29/2004	[5]1,350	13	18.8	37
11N/10W-33A1	10/19/1951	30	—	—	—
	03/20/1952	[5]1,800	—	—	—
	04/16/1952	130	—	—	—
	01/09/1957	[5]1,800	—	—	—
	07/__/1958	[5]1,150	30	—	—
	09/__/1959	600	—	—	—
	09/__/1961	670	[7]40	—	—
	09/19/1963	[5]4,200	—	—	—
11N/10W-33__	01/16/1956	[5]4,200	—	—	—
11N/10W-33G1	10/19/1951	[5]2,900	—	—	—
	03/20/1952	170	—	—	—
	04/17/1952	320	—	—	—
	01/10/1957	60	—	—	—
	07/__/1958	800	10	—	—
	09/__/1959	0	—	—	—
	09/__/1961	70	[7]10	—	—
	09/19/1963	100	—	—	—
	09/23/1964	100	10	—	—
11N/10W-34D1	10/18/1951	[5]2,000	—	—	—
11N/10W-34D2	10/18/1951	[5]4,000	—	—	—

[1]Approximate mid-point of river cross-section on date sampled.

[2]Data collected and analyzed by CADWR not in USGS NWIS (National Water Information System) database; parameter codes are not applicable.

[3]Bicarbonate value calculated from alkalinity.

[4]Nitrate as NO_3 value calculated from nitrite plus nitrate as N.

[5]Value equals or exceeds the State notification level (California Department of Health Services, 2005).

[6]Value equals or exceeds the maximum contaminant level (MCL) or is outside of the acceptable range for primary or secondary Federal and State drinking-water standards (California Department of Health Services, 2003; U.S. Environmental Protection Agency, 2002).

[7]Total recoverable iron.

[8]Total recoverable manganese.

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